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LaRC DESIGN ANALYSIS REPORT

FOR

NATIONAL TRANSONIC FACILITY

FOR

9% NICKEL TUNNEL SHELL

FINITE ELEMENT AND NUMERICAL INTEGRATION ANALYSES OF THE BULKHEAD REGION

VOL. 5

BY

JAMES W. RAMSEY, JR., JOHN T. TAYLOR, JOHN F. WILSON, CARL E. GRAY, JR., ANNE D. LEATHERMAN, JAMES R. ROOKER, AND JOHNNY W. ALLRED

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National Aeronautics and Space Administration

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16. Abstract This report contains the results of extensive computer (finite element, finite difference and numerical integration), thermal, fatigue, and special analyses of critical portions of a large pressurized, cryogenic wind tunnel (National Transonic Facility). The computer models, loading and boundary conditions are described. Graphic capability was used to display model geometry, section properties, and stress results. A stress criteria is presented for evaluation of the results of the analyses. Thermal analyses were performed for major critical and typical areas. Fatigue analyses of the entire tunnel circuit is presented.

The major computer codes utilized are: SPAR - developed by Engineering Information Systems, Inc. under NASA Contracts NAS8-30536 and NAS1-13977; SALORS - developed by Langley Research Center and described in NASA TN D-7179; and SRA - developed by Structures Research Associates under NASA Contract NAS1-10091; "A General Transient Heat-Transfer Computer Program for Thermally Thick Walls" developed by Langley Research Center and described in NASA TM X-2058.

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NTF TUNNEL SHELL

NASA LaRC

FINITE ELEMENT AND NUMERICAL INTEGRATION ANALYSES OF THE BULKHEAD REGION

9% Ni

SEPTEMBER 1976

VOLUME 5

LaRC CALCULATIONS

FOR THE

NATIONAL TRANSONIC FACILITY

TUNNEL SHELL

DATE: SEPTEMBER, 1976

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This report is one volume of a Design Analysis Report prepared by LaRC on portions of the pressure shell for the National Transonic Facility. This report is to be used in conjunction with reports prepared under NASA Contract NAS1-13535(c) by the Ralph M. Parsons Company (Job Number 5409-3 dated September 1976) and Fluidyne Engineering Corporation (Job Number 1060 dated September 1976). The volumes prepared by LaRC are listed below:

1. Finite Difference Analysis of Cone/Cylinder (9% Ni), Vol. 1, NASA TM X73956-1.

2. Finite Element Analysis of Corners #3 and #4 (9% Ni), Vol. 2, NASA TM X73956-2.

3. Finite Element Analysis of Plenum Region Including Side Access Reinforcement, Side Access Door and Angle of Attack Penetration (9% Ni), Vol. 3, NASA TM X73956-3.

4. Thermal Analysis (9% Ni), Vol. 4, NASA TM X73956-4.

5. Finite Element and Numerical Integration Analyses of the Bulkhead Region (9% Ni), Vol. 5, NASA TM X73956-5.

6. Fatigue Analysis (9% Ni), Vol. 6, NASA TM X73956-6.

7. Special Studies (9% Ni), Vol. 7, NASA TM X73956-7.

NTF DESIGN CRITERIA
FOR 9% NICKEL

GENERAL

THE DESIGN OF THE PRESSURE SHELL REFLECTED IN THIS REPORT SATISFIES THE DESIGN REQUIREMENTS OF THE ASME BOILER AND PRESSURE VESSEL CODE, SECTION VIII, DIVISION 1. SINCE DIVISION 1 DOES NOT CONTAIN RULES TO COVER ALL DETAILS OF DESIGN, ADDITIONAL ANALYSES WERE PERFORMED IN AREAS HAVING COMPLEX CONFIGURATIONS SUCH AS THE CONE CYLINDER JUNCTIONS, THE GATE VALVE BULKHEADS, THE BULKHEAD-SHELL ATTACHMENTS, THE PLENUM ACCESS DOORS AND REINFORCEMENT AREAS, THE ELLIPTICAL CORNER SECTIONS, AND THE FIXED REGION (RING S8) OF THE TUNNEL. THE DIVISION 1 DESIGN CALCULATIONS, THE ADDITIONAL ANALYSES AND THE CRITERIA FOR EVALUATION OF THE RESULTS OF THE ADDITIONAL ANALYSES TO ENSURE COMPLIANCE WITH THE INTENT OF DIVISION 1 REQUIREMENTS ARE CONTAINED IN THE TEXT OF THIS REPORT. THE DESIGN ANALYSES AND ASSOCIATED CRITERIA CONSIDERED BOTH THE OPERATING AND HYDROSTATIC TEST CONDITIONS.

IN CONJUNCTION WITH THE DESIGN, A DETAILED FATIGUE ANALYSIS OF THE PRESSURE SHELL WAS ALSO PERFORMED UTILIZING THE METHODS OF THE ASME CODE, SECTION VIII, DIVISION 2.

MATERIAL

THE PRESSURE SHELL MATERIAL SHALL BE ASME, SA-553-1 FOR PLATE AND SA-522 FOR FORGINGS. THE MATERIAL PROPERTIES AT TEMPERATURES EQUAL TO OR BELOW 150°F ARE AS FOLLOWS:

(A) PLATE, 2.0 INCHES OR THINNER

YIELD = 85.0 KSI
ULTIMATE = 100 KSI

(B) WELDS (AUTOMATIC AND SEMIAUTOMATIC)

YIELD = 52.5 KSI
ULTIMATE = 95.0 KSI

(C) WELDS (HAND)

YIELD = 58.5 KSI
ULTIMATE = 95.0 KSI

OPERATING, DESIGN AND TEST CONDITIONS

THE OPERATING, DESIGN AND TEST CONDITIONS FOR THE TUNNEL PRESSURE SHELL AND ASSOCIATED SYSTEMS AND ELEMENTS ARE SUMMARIZED BELOW:

1. OPERATING MEDIUM

   ANY MIXTURE OF AIR AND NITROGEN

2. DESIGN TEMPERATURE RANGE

   MINUS 320 DEGREES FAHRENHEIT TO PLUS 150 DEGREES FAHRENHEIT, EXCEPT IN THE REGION OF THE PLENUM BULKHEADS AND GATE VALVES INSIDE A 23-FOOT, 4-INCH DIAMETER, FOR WHICH THE TEMPERATURE RANGE IS MINUS 320 DEGREES FAHRENHEIT TO PLUS 200 DEGREES FAHRENHEIT.

3. PRESSURE RANGE

	TUNNEL CONFIGURATION	OPERATING PRESSURE RANGE, PSIA	DESIGN PRESSURES PSID
A.	CONDITION I - PLENUM ISOLATION GATES OPEN AND TUNNEL OPERATING:		
	TUNNEL CIRCUIT EXCEPT PLENUM	8.3 to 130	A. 8 EXTERNAL B. 119 INTERNAL
	PLENUM (PLENUM PRESSURE IS LIMITED TO .4 TO 1 TIMES THE REMAINDER OF THE TUNNEL CIRCUIT	3.3 to 130	A. 15 EXTERNAL B. 119 INTERNAL
	BULKHEAD		56 (EXTERNAL TO PLENUM)
B.	CONDITION II - PLENUM ISOLATION GATES OPEN AND TUNNEL SHUTDOWN:		
	ENTIRE TUNNEL CIRCUIT	8.3 to 130	A. 8 EXTERNAL B. 119 INTERNAL
	BULKHEAD		0

C. CONDITION III - PLENUM ISOLATION GATES AND ACCESS DOORS CLOSED:

TUNNEL CIRCUIT EXCEPT PLENUM	8.3 to 130	A. 8 EXTERNAL B. 119 INTERNAL
PLENUM (PLENUM OPERATING PRESSURE CAN EXCEED THE PRESSURE IN THE REMAINDER OF THE TUNNEL CIRCUIT BY 24 PSI, BUT DOES NOT EXCEED THE 130 PSIA MAXIMUM OPERATING PRESSURE)	0 to 130	A. 15 EXTERNAL B. 119 INTERNAL
BULKHEAD		A. 25 (INTERNAL TO PLENUM) B. 119 (EXTERNAL TO PLENUM) FOR MINUS 320 DEGREES FAHRENHEIT TO PLUS 150 DEGREES FAHRENHEIT *C. 110.5 (EXTERNAL TO PLENUM) FOR PLUS 151 DEGREES FAHRENHEIT TO PLUS 200 DEGREES FAHRENHEIT

*OPERATING PROCEDURES LIMIT PRESSURES TO THAT SHOWN.

D. CONDITION IV - PLENUM ISOLATION GATES CLOSED AND ACCESS DOORS OPEN:

TUNNEL CIRCUIT EXCEPT PLENUM	8.3 to 130	A. 8 EXTERNAL B. 119 INTERNAL
PLENUM	14.7	0
BULKHEAD		A. 119 (EXTERNAL TO PLENUM) FOR MINUS 320 DEGREES FAHRENHEIT TO PLUS 150 DEGREES FAHRENHEIT *B. 110.5 (EXTERNAL TO PLENUM) FOR PLUS 151 DEGREES FAHRENHEIT TO PLUS 200 DEGREES FAHRENHEIT

*OPERATING PROCEDURES LIMIT PRESSURES TO THAT SHOWN.

4. HYDROSTATIC TEST DESIGN CONDITIONS

THE PRESSURE SHELL WAS DESIGNED FOR HYDROSTATIC TEST IN ACCORDANCE WITH THE REQUIREMENTS OF THE ASME CODE, SECTION VIII, DIVISION 1. THE TEST PRESSURES SHALL BE AS FOLLOWS. PRESSURE SHELL TEMPERATURE SHALL BE EQUAL TO OR BELOW 100°F DURING HYDROSTATIC TESTS.

CONDITION (1) - MAXIMUM INTERNAL PRESSURE CONDITION FOR THE ENTIRE TUNNEL CIRCUIT

PH_1 = 1.5 (119) + HYDROSTATIC HEAD
= 178.5 PSI + HYDROSTATIC HEAD

CONDITION (2) - MAXIMUM DIFFERENTIAL PRESSURE CONDITION ACROSS THE PLENUM BULKHEADS

PH_2 = 1.5 (119) + HYDROSTATIC HEAD
= 178.5 + HYDROSTATIC HEAD

PH_2* = 1.5 (111.5) $(\frac{23.7}{22.2})$ + HYDROSTATIC HEAD

= 178.5 + HYDROSTATIC HEAD

*TUNNEL OPERATION LIMITATIONS PRECLUDE PRESSURE DIFFERENTIALS ACROSS BULKHEADS IN EXCESS OF 110.5 PSI FOR BULKHEAD AND GATE TEMPERATURES IN EXCESS OF 150°F.

CONDITION (3) - MAXIMUM REVERSE DIFFERENTIAL PRESSURE CONDITION ACROSS THE PLENUM BULKHEADS

PH_3 = 1.5 (25) = 37.5 PSI

THE PRESSURE SHELL EXCEPT FOR THE PLENUM SHALL BE PRESSURIZED TO 141 PSIG. THE PLENUM SHALL BE PRESSURIZED TO 178.5 PSIG.

PRESSURE SHELL STRESS EVALUATION CRITERIA

THIS CRITERIA ESTABLISHES THE BASIS FOR ANALYSIS AND DESIGN OF THE PRESSURE SHELL SO IT WILL MEET OR EXCEED ALL OF THE REQUIREMENTS OF SECTION VIII, DIVISION 1 OF THE ASME BOILER AND PRESSURE VESSEL CODE AND CAN BE STAMPED WITH A DIVISION 1 "U" STAMP.

1. SECTION VIII, DIVISION 1, DIRECT APPLICATION

A. THE MAXIMUM ALLOWABLE STRESS (S)

S = 23.7 KSI (-320°F TO +150°F)

S = 22.2 KSI (-320°F TO +200°F)

(B) PRIMARY BENDING PLUS PRIMARY MEMBRANE STRESSES

THE LOCAL MEMBRANE STRESSES ARE NOT GENERALLY CONSIDERED IN SECTION VIII, DIVISION 1 DESIGNS. HOWEVER, FOR THE PURPOSE OF DESIGNING LOCAL REINFORCEMENT AT BRACKETS, RINGS OR PENETRATIONS NOT COVERED BY DESIGN BASED ON STRESS ANALYSIS, THE LOCAL SHELL MEMBRANE STRESS SHALL BE:

$$P_b + P_m \leq 1.5\ SE$$

NOTE: E IS JOINT EFFICIENCY

2. IN REGIONS OF THE PRESSURE SHELL WHERE DIVISION 1 DOES NOT CONTAIN RULES TO COVER ALL DETAILS OF DESIGN (REF. U-2(g)), ADDITIONAL ANALYSES WERE PERFORMED UTILIZING THE GUIDELINES OF THE ASME CODE, SECTION VIII, DIVISION 2, APPENDIX 4, "DESIGN BASED ON STRESS ANALYSIS." THE BASIC STRESS CRITERIA FOR DIVISION 2 IS REPRESENTED IN FIGURE 4-130.1 AND RESTATED BELOW INDICATING ANY MODIFICATIONS OR EXCESS REQUIREMENTS APPLIED TO IT TO REMAIN WITHIN THE INTENT OF DIVISION 1 AND TO OBTAIN A DIVISION 1 STAMP.

A. GENERAL PRINCIPAL MEMBRANE STRESS

MAXIMUM ALLOWABLE STRESS

S = 23.7 KSI (-320°F TO +150°F)

S = 22.2 KSI (-320°F TO +200°F)

MAXIMUM ALLOWABLE STRESS INTENSITY

S_m = 31.7 KSI (-320°F TO +200°F)

B. PRIMARY GENERAL MEMBRANE STRESS INTENSITY

$$P_m \leq S_m$$

AND IN ORDER TO COMPLY WITH DIVISION 1, THE MAXIMUM PRINCIPAL MEMBRANE STRESS MUST BE:

$$P_m^* \leq S$$

NOTE: THE * IS USED TO DENOTE THAT MAXIMUM PRINCIPAL STRESSES ARE TO BE COMPUTED FOR THE GIVEN LOADING CONDITION. THE INTENT IS TO DETERMINE THE STRESSES WHICH REPRESENT THE HOOP STRESSES AND MERIDIONAL STRESSES WHICH ARE THE STRESSES USED IN DIVISION 1 COMPUTATIONS.

C. DESIGN LOADS, PRIMARY LOCAL MEMBRANE STRESS INTENSITY

$$P_L \leq 1.5\ S_m$$

NOTE: LOCAL MEMBRANE STRESS INTENSITY IS DEFINED IN ACCORDANCE WITH DIVISION 2, APPENDIX 4-112(i). THE TOTAL MERIDIONAL LENGTH IS CONSIDERED TO BE 1.0 $\sqrt{RT}$.

D. DESIGN LOADS, PRIMARY LOCAL MEMBRANE PLUS PRIMARY BENDING STRESS INTENSITY

$$P_L + P_b \leq 1.5\ S_m$$

E. OPERATING LOADS, PRIMARY PLUS SECONDARY STRESS INTENSITY

$$P_L + P_b + Q \leq 3\ S_m$$

F. COMMENT

BECAUSE OF THE LOW YIELD STRENGTH EXPECTED AT THE WELDS AS COMPARED TO THE YIELD STRENGTH OF THE PLATE, STRESS INTENSITIES COMPUTED IN (A), (B), (C), (D), OR (E) SHALL NOT EXCEED THE YIELD STRENGTH OF THE MATERIAL AT EITHER WELD OR PLATE LOCATIONS.

3. A FATIGUE ANALYSIS WAS CONDUCTED IN ACCORDANCE WITH SECTION VIII, DIVISION 2 WITHOUT MODIFICATION.

4. HYDROSTATIC TEST CONDITION DESIGN CONSIDERATIONS

A. PRESSURE SHELL

IN ACCORDANCE WITH DIVISION 1 OF THE ASME CODE, DESIGN ANALYSIS OF THE PRESSURE SHELL FOR THE HYDROSTATIC TEST CONDITION IS NOT REQUIRED. HOWEVER, IN ORDER TO PROVIDE A SATISFACTORY ENGINEERING DESIGN FOR THE PRESSURE SHELL THE FOLLOWING CRITERIA WAS USED:

(a) THE MAXIMUM GENERAL MEMBRANE STRESS PERPENDICULAR TO A WELD LINE WAS LIMITED TO THE LESSER OF:

$$P_m\ * \leq 0.8 \text{ WELD YIELD STRESS}$$

OR

$$P_m\ * \leq 0.5 \text{ WELD ULTIMATE STRESS}$$

(b) THE GENERAL PRINCIPAL MEMBRANE STRESS IN THE PLATE (NOT AT A WELD) WAS LIMITED TO THE LESSER OF:

P_m * $\leq$ 0.8 PLATE YIELD STRESS

P_m * $\leq$ 0.5 PLATE ULTIMATE STRESS

(*) THE STRESSES SATISFYING THIS CRITERIA ARE BASED ON MAXIMUM MEMBRANE STRESSES RATHER THAN INTENSITY CRITERIA.

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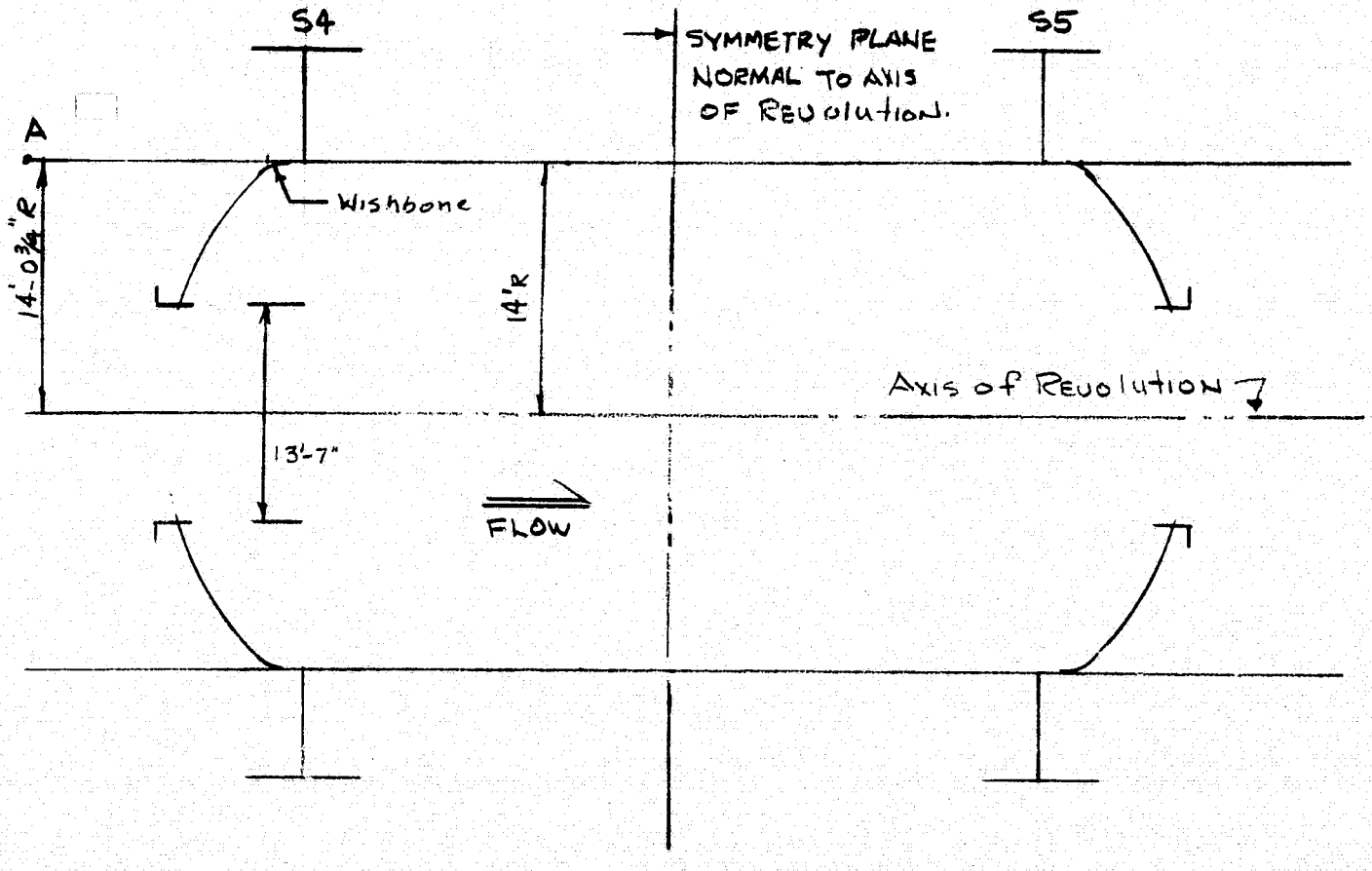

i. SPAR; (a finite element computer code.
developed AND maintained by Engineering Information
System, Inc. UNder NASA CONTRACTS
NAS8 - 30536 AND NAS1 - 13977)

ii. SRA; (a Shells of Revolution computer program
based on a technique of foward integration.
Prepared under Contract NAS1-10091 by
Structures Research Associates.)

The above two codes were used to model
This region of the tunnel, from point A to the
symmetric plane normal to the Axis of revolution.

Spar model description.

Due to a high degree of interconnectivity in the bulkhead/cylindrical shell intersection, and axial symmetry a quarter model using forty element around the circumference was generated.

see figure 1 for a computer plot of the basic geometric construction of the model also, shown on the plot for orientation purposes is the righ-handed orthogonal basis used in defining:

a. rigid body constraints
b. Model geometry
c. direction of all discreet loads.

rigid body Constraints.

Constraints were imposed on the model for the following reasons:

1. To maintain static equilibrium.
The axial displacement on the model had to be removed, to generate a state of equilibrium. This was accomplished by modeling the effective spring rate, from the end of the model to the Axis of symmetry normal to the shell, as rods. Then fixing the end of the rods on the Axis of symmetry.
Thus, any axial forces that were required to set up the proper stress state in the shell elements would be self generating. (See fig. 2.)
Changing the spring rates was found to have no effect on the general structure.
This simply caused the model to seek a new relative equilibrium point before setting its stress state.

2. Symmetry boundary conditions.

The (1,3) and (2,3) planes were modeled as planes of symmetry. So that in effect a full 360° model was constructed. see fig. 1.

3. IMpose Continious Cylindrical shell boundary Conditions.

On the upstream shell the rotation were removed and all translational degress of freedom were left in the model. By removing the rotations, moments were generated to simulate a Continious cylindrical shell.

The down stream shell had the same boundary conditions, with The exception of the rods being attached to these points.

Note: Rod element are not capable of transmitting bending moments. So all bending moments had to be taken out by the shell elements. See fig. 2.

all other degrees of freedom were left in the model.

The model had 2009 nodes or, after imposing all the boundary condition, a little less than 12,000 degrees of freedom.

Model geometry

As previously mentioned a quarter model, with 40 elements around the circumference and 2009 nodes, was generated.
all elements were membrane and bending flat plates.

approximately six feet, of the
The cylindrical shell, was modeled on either side of the bulkhead / shell intersection.

a detailed sketch of this intersection is shown in figure 3. The extra metal around the 3" radius from a modeling stand point is rather difficult to model. Therefore, this section was modeled as shown in figure 4.
leaving out this extra stiffness, by not connecting say points A and B (see fig. 4) with elements that would exhibit the same stiffness, no unusually high stresses were found to exist.

Modeling of the extra shell lengths served two main purposes:

First the bulkhead / shell intersection effect on the shell had to be determined. IT was found that this discontinuity had no adverse effect on the shell, and tends to die out very quickly.

Second, a check point on the model had to be built-in so that one might conclude that the appropiate loads and boundary conditions had been imposed. Stresses on the shell boundarys showed that little or no bending was taking place and hand calculation could predict the stress in these regions.

The gussets on the bulk head flange were modeled as plate elements connecting the flange to the bulk head reinf. see fig. 1.

The support ring S4 was modeled with plate elements and stem of the ring connected directly into the shell at point c (see fig. 4)

The joint numbering sequence started at the top of the flange surface, at Theta equal 0° increased in the theta direction first, then along the meridian. The joint numbering sequences are shown in figures 18 thru 22.

The shell section properties (plate thickness) where model as indicated in fig. 1. all tapers, except for down stream transition from t= 2.00" to t = 1.75", were modeled as an average of the two adjacent thickness.

Section properties are shown in figures 23 thru 29.

Section properti numbers and their corresponding thickness are listed below.

Sect. No.	THICKNESS	Sect. No.	THICKNESS
1	4.000	9	1.750
2	5.000	10	1.250
3	3P00	11	1.500
4	1.875	12	2.4375
5	1.875	13	1.000
6	2.000	14	2.000
7	2.000	15	2.000
8	1.000	16	2.000

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Material Properties used in this analysis are listed below.

9% NI.

ρ	$.283\ lb/in^3$	density
α	$.533 \times 10^{-5}\ in/in/F$	Coef. Ther. exp.
E	29×10^6 PSI	Mod of elast.
ν	.3	Poisson's ratio

Table 17. Selected Thermal Properties of Some Steels
(See also Tables 5A and 5B, Page 12)

3½% Nickel Steel	
Thermal Expansion Coefficient	
0 to +200°F	6.15 x 10^{-6} in./in./°F
Thermal Conductivity	
−150°F (mean)	214 Btu/in./hr./ft²/°F
+68°F (mean)	253 Btu/in./hr./ft²/°F
+200°F (mean)	270 Btu/in./hr./ft²/°F
Specific Heat	
−150 to +80°F	0.798 Btu/lb./°F
+80 to +1000°F	0.147 Btu/lb./°F
9% Nickel Steel	
Thermal Expansion Coefficient	
At room temperature	5.8 x 10^{-6} in./in./°F
−300 to 0°F (avg.)	5.3 x 10^{-6} in./in./°F
−300 to −200°F (avg.)	5.6 x 10^{-6} in./in./°F
at −300°F	4.0 x 10^{-6} in./in./°F
Thermal Conductivity	
−320°F	91.3 Btu/in./hr./ft²/°F
−150°F	169.0 Btu/in./hr./ft²/°F
+68°F	189.0 Btu/in./hr./ft²/°F
+200°F	209.0 Btu/in./hr./ft²/°F
Specific Heat	
−320 to +80°F	0.0878 Btu/lb./°F (avg.)
+80 to +700°F	0.119 Btu/lb./°F (avg.)
304 Stainless Steel	
Thermal Expansion Coefficient	
+32 to +212°F	9.6 x 10^{-6} in./in./°F
−300 to +70°F (mean)	7.3 x 10^{-6} in./in./°F
+70 to +1000°F (mean)	10.0 x 10^{-6} in./in./°F
at −300°F	5.9 x 10^{-6} in./in./°F
Thermal Conductivity	
−320°F	56.4 Btu/in./hr./ft²/°F
−155°F	90.0 Btu/in./hr./ft²/°F
+70°F	113.0 Btu/in./hr./ft²/°F
+600°F	120.0 Btu/in./hr./ft²/°F
Specific Heat	
−320°F	0.037 Btu/lb./°F (avg.)
−150°F	0.088 Btu/lb./°F (avg.)
+ 80°F	0.120 Btu/lb./°F (avg.)

5.5 x 10^{-6}

Loadings

The following loading cases were run:

Case 1. Gate Valve Closed

Case 2. Gate Valve open

Case 3. Full pressure

Case 4. Dog loads, No pressure

Case 5. Dog loads, Valve Closed Pressure

Case 6. Gate Valve open, Temperature distribution

Case 7. Gate Valve Closed, Transient Temp. dist.

To AID IN explaining the different loading configuration refer to fig 2 and 5.

P_1 is a nodal pressure applied to all nodes on the upstream shell and bulkhead.

P_2 is a nodal pressure applied to all nodes on the downstream shell and bulkhead.

P_3 is a nodal pressure applied to all nodes on the upstream and downstream shell.

LG is a nodal force applied to each node around the circumference, except for the nodes on the $\theta = 0° \& 90°$ axis, here the magnitute of LG is 1/2.
This load is due to a sealing force generated by the gate valve, and/or dog preload loads

LD is a nodal force applied in pairs of nodes at dog locations.
These loads are spring preload or reactions to AFEA loads.

LS is a nodal force
1. applied in pairs of nodes at dog locations for valve closed conditions
2. applied to each node around the circumference, except for nodes located on the $\theta = 0° \& 90°$ axis, here

for value open configuration.

LTF is a nodal force applied in pairs of nodes at dog locations. These loads are spring preloads

M is a nodal moment applied to each node around the circumference except for nodes located on the $\theta = 0° \& 90°$ axis, here the magnitude is 1/2. This moment is a result of an assumed misalignment of components.

F is a nodal force applied to each node around the circumference except for nodes located on the $\theta = 0 \& \theta = 90°$ axis, here the magnitude is 1/2. This is a boundary load due to capping off the end of the cylinder.

Case 1. Gate valve Closed

For this loading configuration The following loads were applied:

P_1 = 119.0 PSIa
P_2 = 0.0 PSIa
P_3 = 0.0 PSIa
LG = -17483.0 lbs
LS = 19500.0 lbs
LTF = -19500.0 lbs
F = 66242.0 lbs
LD = 0.0 lbs
M = 0.0 IN-lbs

Case 2. Gate Valve open / running condition

For this loading configuration the following loads were applied:

P_1 = 133.7 psia
P_2 = 53.4 psia
P_3 = 14.7 psia

actual down stream shell pressure 57.6 PSIG.

LD = 13000. lbs.
LG = -5568.8 lbs.
LS = 3018.8 lbs.
LTF = -19500. lbs.
M = 145275. in-lbs
F = 66243. lbs.

Case 3. Full pressure

For this loading configuration The following loads were applied:

P_1 = 119 PSIa
P_2 = 119 PSIa
P_3 = 0 PSIa
F = 66242 lbs.
LG = 0. lbs.
LD = 0. lbs.
LTF = 0. lbs.
LS = 0. lbs.
M = 0. IN-lbs

This loading case was run primarily for superposition of shell stresses on a S4 AND S5 asymmetric ring load analysis.

Case 4 Dog loads

For this loading configuration the following loads were applied:

LG = -7800. lbs
LD = 19500. lbs
LS = 0.
LTF = 0.
P_1 = 0.
P_2 = 0.
P_3 = 0.
F = 0.
M = 0.

This loading case was run to see the effect of the dog loads on the sealing surface under a complete static condition. (ie no other loads)

Case 5 Dog loads, Valve Closed pressure

For this loading configuration the following loads were applied:

L_G = -7800. lbs
L_D = 19500. lbs
P_1 = 119.0 PSIA
F = 66242. lbs
L_S = 0.
L_{TF} = 0.
M = 0.
P_2 = 0.
P_3 = 0.

This load case was run to see the effect of the dog loads on the sealing surface under a complete static valve closed condition.

Case 6 Gate Valve open w/ TEMP. DIST.

For this loading configuration
the following loads were applied:

P_1 = 133.7 PSIA
P_2 = 53.4 PSIA
P_3 = 14.7 PSIA

actual downstream shell pressure 57.6 PSIG.

LD = 13000. lbs
LG = -5568.8 lbs
LS = 3018.8 lbs
LTF = -19500. lbs
M = 145275. IN-lbs
F = 66242. lb

AND The temperature distribution shown in figure 7a. was applied. This temperature distribution was uniform Through the element thickness and around the circumference of the model.

Case 7 Gate Valve closed w/ Tran. Temp dist.

For this loading configuration the following loads were applied:

P_1 = 119. PSIa
P_2 = 0.0 PSIa
P_3 = 0.0 PSIa
LG = -17483.0 lbs
LS = 19500.0 lbs
LTF = -19500.0 lbs
F = 662420 lbs
LD = 0.0 lbs
M = 0.0 IN-lbs

And the temperature distribution shown in figure 7b. was applied This Temperature distribution was uniform through the element thickness and around the circumference of the model.

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Stress and deflection results

Presented with the summary results for the following cases, except for the dog loadings, are computer stress plots. where the circumferential (SX) or meridian (SY) nodal stresses are given for,

mid-surface (Surface 0),
inside surface (surface 1), and
outside surface (surface 2).

The stresses are plotted for joint one of the element (reference figure 6e) for the element defined by the joints 1 2 43 42, Joint one for that element is node 1.

Nodal stresses for a joint are given from the four surrounding elements. IF any discrepancies exist in the stresses for a joint due to discontinuties in the structure (ie. rings, cone-cyl junct.) The larger value is used in the interpretation of the results.

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Results. load Case 1

Value Closed

The following table is a list of the max and min principle stresses at the joints indicated. Also, in the Table is the max benging stress at these nodes and the surface they accure on.

Surface A = inside surface.
Surface B = outside surface.

Node SEE fig. 6	MAX PS	MIN PS	@Bending Surf.		
1	-1.41	-3.57	-4.84A		
83	-.01	-3.46	-3.09A		
124	-.73	-3.80	-4.29 A		
206	-.04	-8.29	-8.27 A		
288	-2.10	-9.14	-9.83 A		
329	-1.04	-9.33	-10.18A		
370	-4.37	-9.97	-16.39 A		
411	-4.17	-10.02	-17.45B		
452	-4.54	-9.32	-10.57 B		
493	-4.73	-7.89	-8.00 A		
534	-4.73	-7.89	-7.97 A		
575	-7.72	-7.92	-9.22A		
616	-7.52	-7.70	-9.[illegible] B		
657	-6.56	-7.60	-13.02B		
698	-2.92	-7.35	-16.00B		
739	1.86	-6.89	-13.43 B		
780	10.48	-5.98	-17.9 A		
821	12.50	-5.70	-25.34A		
862	12.34	-5.45	-22.76A		
903	10.32	-5.58	-[illegible].2A		
944	10.72	5.00	20.0[illegible]		
985	13.04	5.00	15.42 A		
1140	20.35	10.00	20.46 A		
1272	7.48	-.10	7.69 B		
1559	5.79	-.10	7.43 A		
1641	1.84	-.10	5.43A		
1805	-.12	-.71	.73 B		
1887	.04	-.12	.32A		

Shown in figures 30 thru 56 are stress plots for this loading configuration.

The stresses shown are not principle stresses however, due to the symmetry in the geometry and loads there is very little transverse shear. Thus, these stress values could be treated as principle stresses.

Membrane stress (intensity)

Primary local membrane stress intensity (node 821)

$\sigma_1 = 12.10$ KSI
$\sigma_2 = -5.72$ KSI
$\sigma_3 = -.06$ KSI

$S_{12} = 12.10 - (-5.72) = 17.82$ KSI
$S_{23} = -5.72 - (-.06) = -5.66$ KSI
$S_{31} = -.06 - 12.10 = -12.16$ KSI

$S = |17.82| = 17.82$ KSI

$P_m = 17.82 < S_m = 31.7$ KSI ok

Since the stress intensity is $< S_m$ (31.7 KSI) The stress intensity meets the criteria for general membrane stress [illegible].

General membrane stress
$S = 20.35$ (shell, node 1190)
$20.35 \leq 23.7$ KSI

This region meets the stress evaluation criteria for the general membrane stress.

Primary plus secondary stress intensity

Inside surface (upstream shell side)

$\sigma_1 = 6.34$ KSI

$\sigma_2 = -25.25$ KSI

$\sigma_3 = -.119$ KSI

$S_{12} = 6.34 - (-25.25) = 31.59$ KSI

$S_{23} = -25.25 - (-.119) = -25.131$ KSI

$S_{31} = -.119 - 6.34 = -6.459$ KSI

$S = |31.59| = 31.59$ KSI

$P_L + P_b + Q < \sigma_{yp}$ (Weld) $= 52.5$ OK

OUT side surface

$\sigma_1 = 17.86$ KSI
$\sigma_2 = 13.82$ KSI
$\sigma_3 = 0.$ KSI

$S_{12} = 17.86 - 13.82 = 4.04$
$S_{23} = 13.82 - 0 = 13.82$
$S_{31} = 0 - 17.86 = -17.86$
$S = |-17.86| = 17.86$ KSI

$P_L + P_b + Q < S_{yp}$ (weld) $= 52.5$ KSI

$17.86 < 52.5$ KSI ok

The primary plus secondary stress intensity meets the stress evaluation criteria.

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Hydo test Conditions

The hydo test pressure was assumed to be the max. pressure at the bottom of the tunnel for the region under consideration.

$$P_H = 1.5 \times 119 + \frac{62.4}{144}\left(\frac{41'}{2} + \frac{28}{2}\right) = 193.45 \text{ PSI}$$

Stress scale factor = 193.45 / 119 = 1.626

The max. general membrane stress ⊥ to weld is smaller of

$P_m \leq 0.8 \times 52.5 = 42.0$ KSI

or

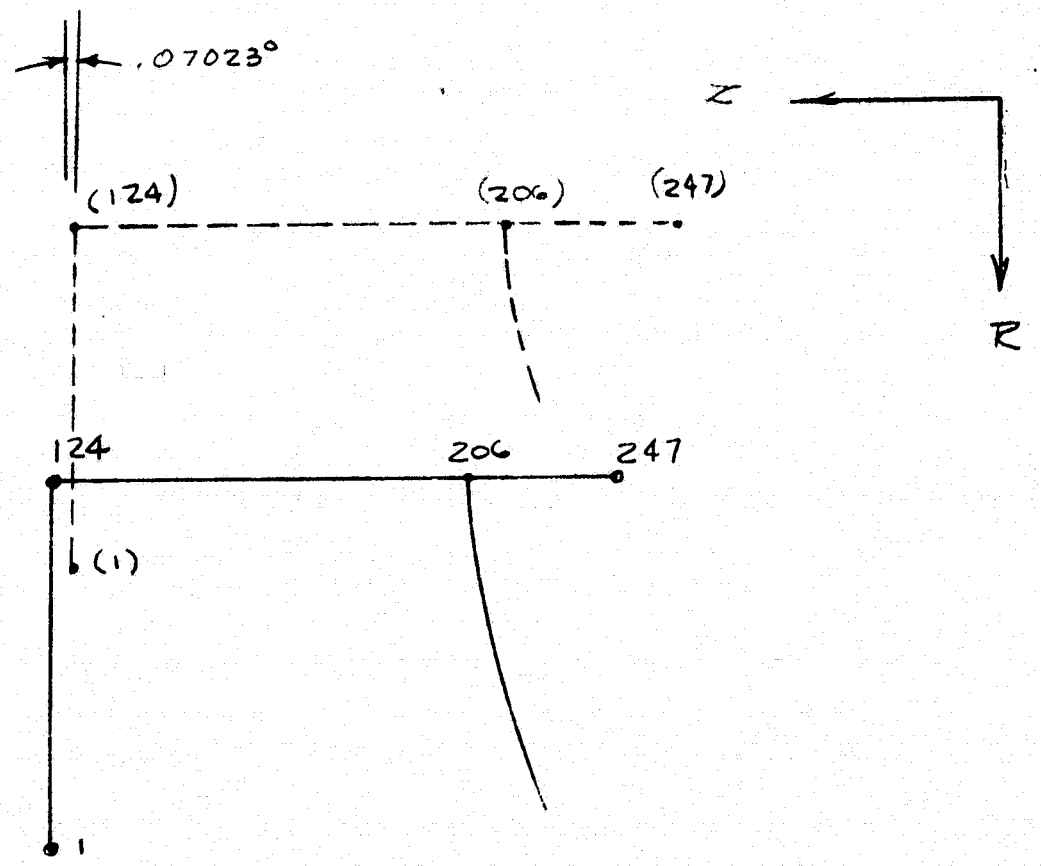
$P_m \leq .5 \times 95 = 47.5$ KSI

$S = 1.626 \times 20.35 = 33.08$ KSI

$33.05 < 42.0$ KSI

This region meets the stress evaluation criteria for hydro test conditions.

The following sketch and table shows the relative displacement and indicates the rotation of the sealing surface.



DISPLACEMENTS

Joint	Δ R IN.	Δ Z IN.
1	-0.0102	-0.154
124	-0.0103	-0.135
206	-0.0232	-0.135
247	-0.0282	-0.135

Results load Case 2

Valve Open / running Condition

Due to the decreased pressure differential across the bulk head (76.3 psig) and the down stream pressure being far less than design (57.6 psig VS 119.0 psig, design). stresses were as expected very low and futher analysis of this loading condition was not warrented.

Stresses for this loading condition:

Upstream and down stream shell,
Here the stresses are equal to those generated from case 1 (see figures 57 thru 83 and Compare to figures 30 thru 56)

∴, this region meets the stress evaluation criteria.

Bulk head;
Here the stresses are less than those generated from case 1 (see figures 31 thru 37 and compare to figures 58 thru 63).

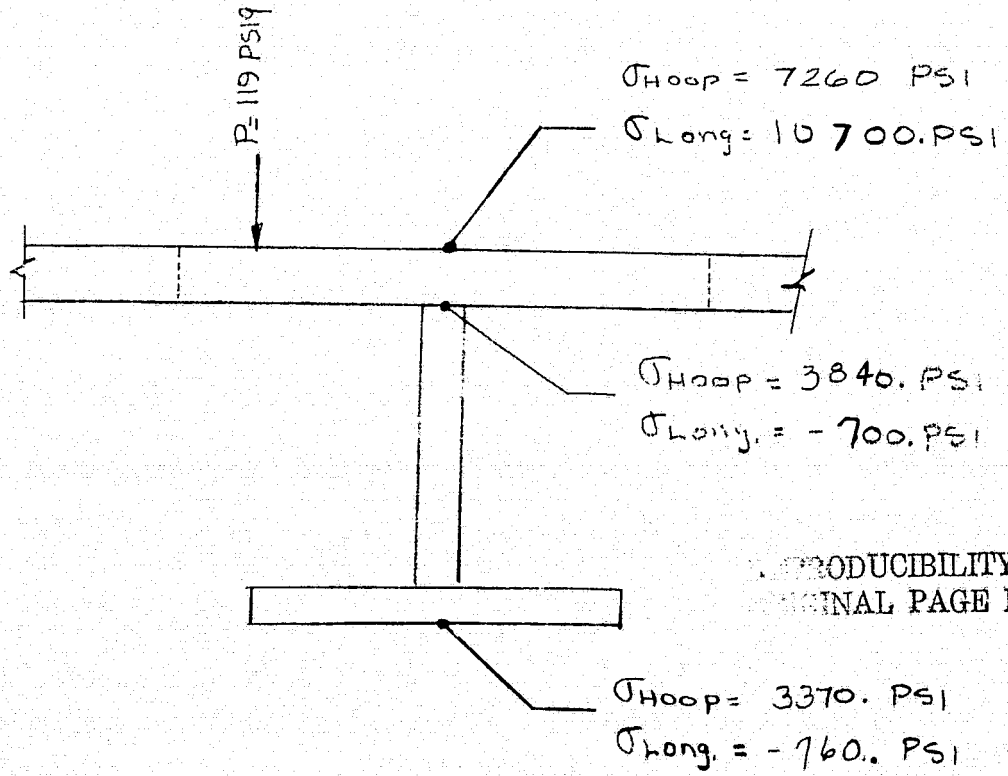
∴, this region meet the stress evaluation criteria for this loading condition.

Results load Case 3

Full Pressure

Below is a sketch of the stress picture used on a S4 and S5 asymmetric ring load analysis.

Refer to section "S4 & S5 ring analysis" for composite analysis of this support ring region.



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S4 or S5

figures 84 thru 110 show the general stress picture of the

BY _____ DATE _____ SUBJECT _____ SHEET NO. 37 OF _____

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Results load Case 4 & 5

Dog loads No Pressure

Dog loads Value closed Pressure

The following table has the z displacements for:

Case 4 computer run number DNY with a 39 kip load per dog only

Case 5 computer run number FIR. with a 39 kip load per dog and a Gate Valve closed pressure loading.

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DNY = CASE 4
FIR = CASE 5

JLOC	DNY	FIR	JLOC	DNY	FIR	JLOC	DNY	FIR	JLOC	DNY	FIR
1	.0057	-.151	42	.0025	-.152	83	-.0012	-.158	124	-.0063	-.165
2	.0079	-.148	43	.0038	-.151	84	-.00068	-.158	125	-.0064	-.165
3	.0104	-.145	44	.0058	-.150	85	-.000173	-.157	126	-.00659	-.165
4	.0104	-.145	45	.0058	-.150	86	.000173	-.157	127	-.00659	-.165
5	.0079	-.148	46	.0038	-.151	87	-.00068	-.158	128	-.0064	-.165
6	.0057	-.151	47	.0025	-.152	88	-.0012	-.158	129	-.0063	-.165
7	.0079	-.148	48	.0038	-.151	89	-.00068	-.158	130	-.0064	-.165
8	.0104	-.145	49	.0058	-.150	90	.000173	-.157	131	-.00659	-.165
9	.0104	-.145	50	.0058	-.150	91	.000173	-.157	132	-.00659	-.165
10	.0079	-.148	51	.0038	-.151	92	-.00068	-.158	133	-.0064	-.165
11			52			93			134		
12			53			94			135		
13	"	"	54	"	"	95	"	"	136	"	"
14			55			96			137		
15			56			97			138		
16			57			98			139		
17			58			99			140		
18	"	"	59	"	"	100	"	"	141	"	"
19			60			101			142		
20			61			102			143		
21			62			103			144		
22			63			104			145		
23	"	"	64	"	"	105	"	"	146	"	"
24			65			106			147		
25			66			107			148		
26			67			108			149		
27	"	"	68	"	"	109	"	"	150	"	"
28			69			110			151		
29			70			111			152		
30			71			112			153		
31			72			113			154		
32			73			114			155		
33	"	"	74	"	"	115	"	"	156	"	"
34			75			116			157		
35			76			117			158		
36	.0057	-.151	77	.0025	-.152	118	-.0012	-.158	159	-.0063	-.165
37	.0079	-.148	78	.0038	-.151	119	-.00068	-.158	160	-.0064	-.165
38	.0104	-.145	79	.0058	-.150	120	.000173	-.157	161	-.00659	-.165
39	.0104	-.145	80	.0058	-.150	121	.000173	-.157	162	-.00659	-.165
40	.0079	-.148	81	.0038	-.151	122	-.00068	-.158	163	-.0064	-.165
41	.0057	-.151	82	.0025	-.152	123	-.0012	-.158	164	-.0063	-.165

Reviewing the relative displacements of the sealing surface face on the bulkhead flange. It is apparent that the warpping distortion of this surface does not deform enough between relative adjacent points To cause a break in the seal between the bulkhead and gate valve.

Therefore, under the combined effect of joining and pressure, the flange design is ok.

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RESULTS LOAD CASE 6

GATE VALVE OPEN / RUNNING CONDITION W/ STEADY STATE TEMPERATURE DISTRIBUTION.

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THE FOLLOWING TABLE IS A LIST OF THE MAX. AND MIN. principal STRESSES AT THE JOINTS INDICATED. ALSO, IN THE TABLE IS THE MAX BENDING STRESS AT THESE NODES AND THE SURFACE THAT THEY ACCURE ON.

SURFACE A - INSIDE SURFACE

SURFACE B - OUT SIDE SURFACE

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NODE See Fig 6	Max Ps Membrane	MIN Ps Membrane	Sbending / surface
1	.60	-1.15	1.97 / B
83	1.13	-.65	-2.50/A
124	-1.31	-4.17	6.15/A
206	-.15 .57	-4.0 -3.77	-4.05/A -4.87/A
288	.37	-5.31	-6.84/A
329	1.52	-5.56	-6.99/A
370	-2.15	-6.49	-12.51/A
411	-1.31	-8.17	-14.79/B
452	-2.03	-7.59	-9.39/B
493	-2.25	-6.83	-7.68/B
534	-2.94	-6.35	-7.32/B
575	-3.92	-5.89	-8.04/B
616	-4.01	-5.72	-9.77/B
657	-4.07	-5.86	-11.45/B
698	-2.75	-4.05	-12.59/B
739	-3.67	-3.88	-10.87/B
780	11.80	-3.27	11.84/A
821	7.80	-3.12	-14.26/A
862	13.44	-2.99	17.45/B
903	17.34	-3.14	23.02/B
944	8.58	5.00	20.02/B
985	5.00	4.48	14.02/B
1190	22.08	10.00	22.37/B
1272	5.42	2.04	6.31/B
1559	5.74	2.04	6.50/B
1641	6.13	2.04	6.32/B
1805	5.61	2.33	5.67/A
1887	5.50	2.33	5.57/B
247	-.15	-6.00	-6.14/A

SHOWN IN FIGURES 111 THRU 137 ARE STRESS PLOTS FOR THIS LOADING CONFIGURATION

THE STRESSES SHOWN ARE NOT PRINCIPAL STRESSES.

HOWEVER, DUE TO THE SYMMETRY IN THE GEOMETRY AND LOADS THERE IS VERY LITTLE TRANSVERSE SHEAR. THUS, THESE STRESS VALUES COULD BE TREATED AS PRINCIPAL STRESSES.

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MEMBRANE STRESS (INTENSITY)

PRIMARY LOCAL MEMBRANE STRESS INTENSITY (NODE 903)

$\sigma_1 = 17.34$ KSI

$\sigma_2 = -3.14$ KSI

$\sigma_3 = -.06$ KSI

$S_{12} = 17.39 - (-3.14) = 20.48$ KSI

$S_{23} = -3.14 - (-.06) = -3.08$ KSI

$S_{31} = -.06 - 17.34 = 17.40$ KSI

$S = |20.48| = 20.48$ KSI

$P_m = 20.48$ KSI $<$ $S_m = 31.7$ KSI

SINCE THE STRESS INTENSITY IS $<$ Sm (31.7 KSI) THE STRESS INTENSITY MEETS THE CRITERA FOR GENERAL MEMBRANE STRESS INTENSITY

GENERAL MEMBRANE STRESS

$S = 22.08$ KSI (SHELL NODE 1190)

$22.08 < S = 23.7$ KSI

THIS REGION MEETS THE STRESS EVALUATION CRITERIA FOR GENERAL MEMBRANE STRESS

PRIMARY PLUS SECONDARY STRESS INTENSITY

INSIDE SURFACE (NODE 903)

$\sigma_1 = 11.66$ KSI

$\sigma_2 = -22.28$ KSI

$\sigma_3 = -.119$ KSI

$S_{12} = 11.66 - (-22.28) = 33.94$ KSI

$S_{23} = -22.28 - (-.119) = -22.161$

$S_{31} = -.119 - 11.66 = 11.78$ KSI

$\sigma = (33.94) = 33.94$ KSI

$P_L + P_b + Q = 33.94 < \sigma_{yp} = 52.5$ KSI OK

OUTSIDE SURFACE

$\sigma_1 = 23.02$ KSI

$\sigma_2 = 16.00$ KSI

$\sigma_3 = 0.0$ KSI

$S_{12} = 23.02 - 16.00 = 7.02$ KSI

$S_{23} = 16 - 0 = 16.00$ KSI

$S_{31} = 0 - 23.02 = -23.02$ KSI.

$S = |-23.02| = 23.02$ KSI

$P_L + P_b + Q = 23.02 < \sigma_{yp} = 52.5$ KSI OK

THE PRIMARY PLUS SECONDARY STRESS INTENSITY MEETS THE STRESS EVALUATION CRITERIA.

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Results load Case 2

Valve Closed w/ transient temperature dist.

t = 30.0 min warm up time.

THE FOLLOWING TABLE IS A LIST OF THE MAX. AND MIN. PRINCIPAL STRESSES AT THE JOINTS INDICATED.

ALSO, IN THE TABLE IS THE MAX. BENDING STRESS AT THESE NODES AND THE SURFACE THAT THEY ACCURE ON.

SURFACE A - INSIDE SURFACE

SURFACE B - OUTSIDE SURFACE

Node See fig 6	Max PS Membrane	MIN PS membrane	Bending /surf
1	13.95	1.42	17.71 /A
83	14.75	-1.51	16.58/A
124	7.60	-2.10	-10.75/B
206	-1.07 -7.49	-46.31 -48.20	-47.62/B -49.72/B
288	1.31	-7.63	-8.85 /B
329	.99	-8.60	-10.16 /B
370	-.74	-5.69	-9.56 /B
411	3.74	-4.69	-10.54/A
452	-.35	-4.93	-6.40/B
493	-3.20	-4.73	-7.73 /B
534	-5.00	-5.84	-10.50/B
575	-5.97	-7.55	-15.51/B
616	-7.57	-8.12	-15.61/B
657	-7.62	-9.60	-16.79/B
698	-4.59	-7.48	-20.22
739	1.88	-6.95	-19.56
780	15.26	-5.87	15.33/B
821	23.57	-5.48	27.26/B
862	25.73	-5.23	31.28/B
903	19.29	-5.48	-30.99/A
944	11.82	5.00	14.06/B
985	7.90	5.00	10.16/B
1190	20.52	10.00	20.64/A
1272	10.45	-.10	13.31B
1559	7.54	-.10	9.58/B
1641	5.10	-.10	5.16/B
1805	-.12	-.35	—
1887	-.11	-.12	—
247	-.07	-49.0	-49.04/A

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Shown in figures 138 thru 160 are stress plots for this loading configuration The stresses shown are not principle stresses. however, due to the symmetry in the geometry and loads there is very little transverse shear. Thus, these stress values could be treated as principle stresses.

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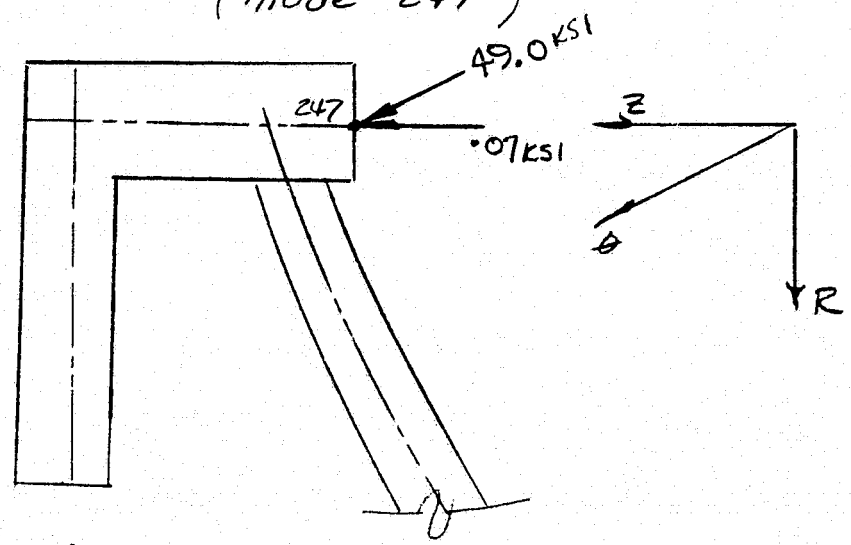
_____ _____ _____

General thermal stresses

(Mode 247)



$\sigma_1 = -.07$ KSI

$\sigma_2 = -49.0$ KSI

$\sigma_3 = 0.0$ KSI

$S_{12} = -.07 - 49.0 = 48.93$ KSI

$S_{23} = -49.0 - 0 = -49.0$ KSI

$S_{31} = 0 - (-.07) = .07$ KSI

$P_L + P_b + Q = |-49.00| = 49.0$ KSI

49.0 KSI $< \sigma_{yp}$ (weld) $= 52.5$ KSI. OK

BY _____ DATE _____
CHKD. BY _____ DATE _____

SUBJECT _____

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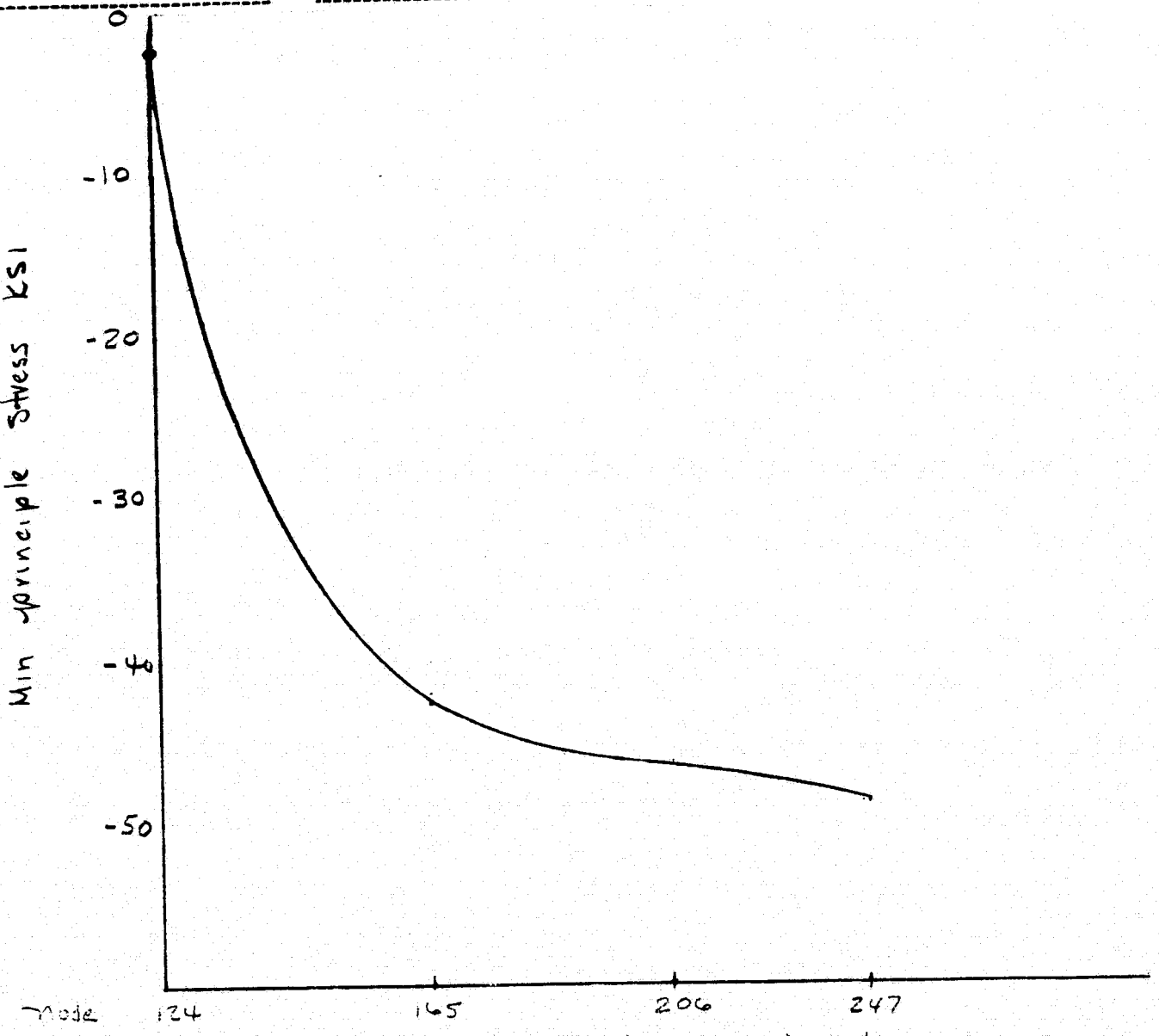
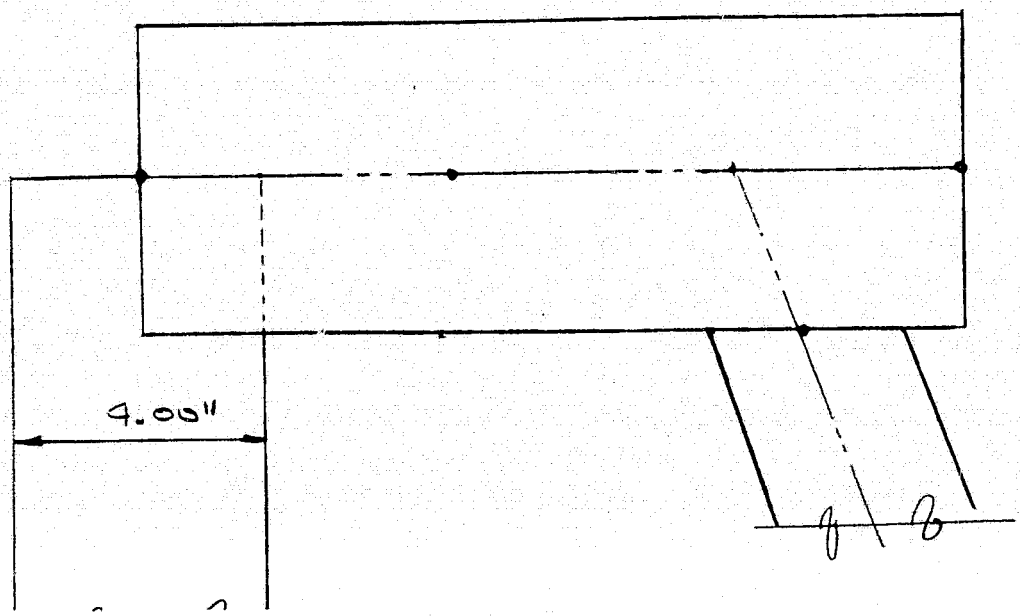
JOB NO. _____





Membrane stress (intensity)
(away from hatch opening)

Primary local membrane stress intensity
(node 862)

$\sigma_1 =$ 25.73 KSI
$\sigma_2 =$ -5.23 KSI
$\sigma_3 =$ -.06 KSI

$S_{12} = 25.73 - (-5.23) = 30.96$ KSI
$S_{23} = -5.23 - (-.06) = 5.29$ KSI
$S_{31} = -.06 - 25.73 = 25.79$ KSI

$S = |30.96| = 30.96$ KSI

$P_M = 30.96 \leq 31.7$ KSI ok

Since the stress intensity is < Sm (31.7 KSI)
The stress intensity meets the criteria
for general membrane stress intensity.

General membrane stress
(shell, node 20.52 KSI)
$S = 20.52$ KSI

$20.52 \leq 23.7$ KSI

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This region meets the stress evaluation
criteria for the general membrane stress.

Primary plus secondary stress intensity

inside surface (upstream shell side)
(node 208)

$\sigma_1 = -11.49$ KSI

$\sigma_2 = -51.02$ KSI

$\sigma_3 = -.119$ KSI

$S_{12} = -11.49 - (-51.02) = 39.53$

$S_{23} = -51.02 - (-.119) = -50.9$

$S_{31} = -.119 - (-11.49) = 11.37$

$S = |-50.9| = 50.9$ KSI

$P_L + P_b + Q = 50.9 < S_{yp}$ (Weld) $= 52.5$ ok.

Outside Surface
(Node 249)

$\sigma_1 = -1.25$ KSI
$\sigma_2 = -49.94$ KSI
$\sigma_3 = 0$ KSI

$S_{12} = -1.25 - (-49.94) = 48.69$ KSI
$S_{23} = -49.94 - 0 = -49.94$ KSI
$S_{31} = 0 - (-1.25) = 1.25$ KSI

$S = |-49.94| = 49.94$ KSI

$P_L + P_b + Q = 49.94 < \sigma_{yp}(\text{Weld}) = 52.5$ KSI OK

The primary plus secondary stress intensity meets the stress evaluation criteria.

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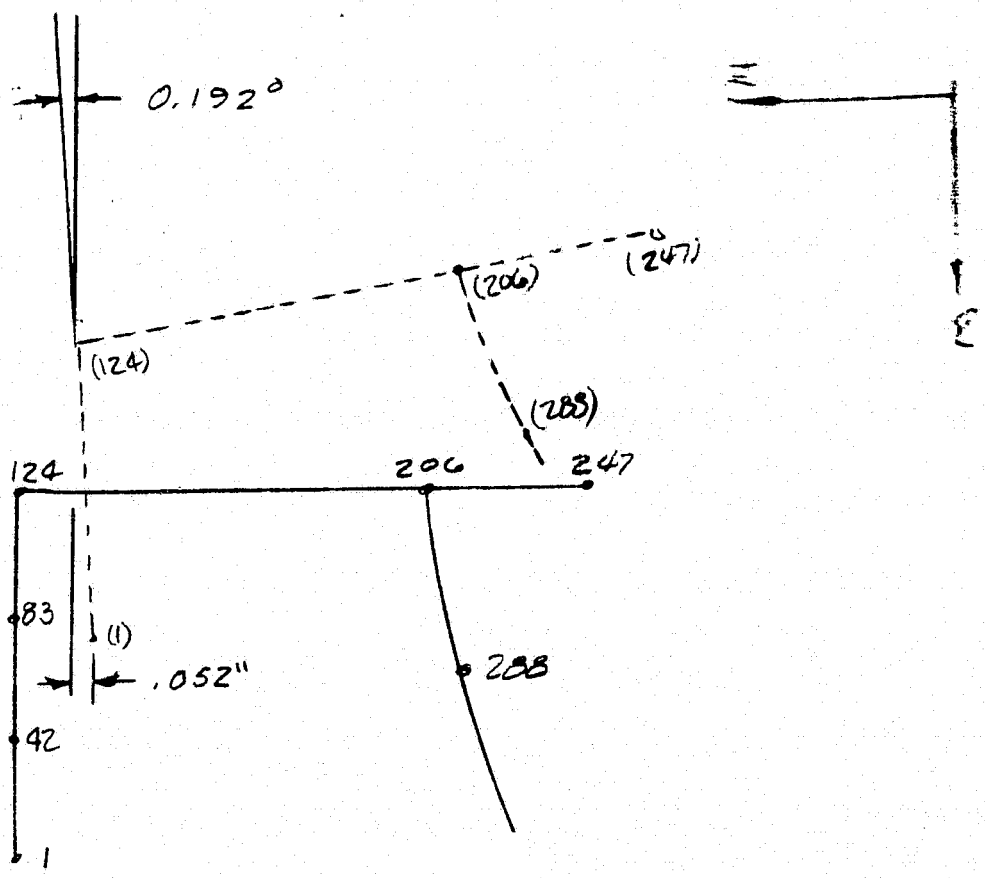
Relative rotation of the flange under this combined pressure and thermal loading is very small. Thus, indicating no problem of separation between gate valve and bulkhead.

See the following sketch and table of values taken from computer run BAI.

BY_____ DATE_____ SUBJECT_____ SHEET NO. 58

CHKD. BY_____ DATE_____ JOB NO _____



Displacements

Joint	ΔR IN.	ΔZ IN.
1	-0.0948	-.342
124	-0.0713	-.290
206	-0.0956	-.293
247	-0.104	-.296
288	-0.101	-.301
42	-.0856	-.322
83	-.0792	-.308

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SRA Model description

SRA was used to compute a linear and a non-linear stress and displacement responce under symmetric loads.

The structure was assumed to be an axisymmetric structure.
See figure 8 for a computer plot of the meridional surface.
also, shown on the plot is the right-handed Triad (s, θ, z) used in defining:

a. rigid body constraints
b. Model geometry
c. direction of all discreet loads
d. location of all bifrication points.

Rigid body Constraints

Boundary conditions were imposed as shown in figure 8.

on the up stream shell the axial displacement as well as rotations were taken out. This forced the model to generate it's own axial forces when pressure was applied across the bulkhead.

On the down stream shell only the rotation were taken out.

Model geometry

As previously stated the structure was axisymmetric with the exception of the bulkhead flange gussets.

These gussets were modeled as stringers. where their addition stiffness was smeared along both the back side of the flange and bulkhead in the areas of their actual location.

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The model was constructed with 31 subsections (the "+" marks on fig. 8-11) with stress recovery points at the beginning, middle and ending of each subsection.

The subsections or fictitious boundaries were inserted to:

a. limit the subinterval length ($\Delta \ell < 3\sqrt{rt}$)
b. locate rings (indicate on figs by an "O")
c. points of discreet loads.
d. locate a branch point in the shell.

The bulkhead insulation rings were included in this model. They were input as discreet ring properties at the rings' centroid located relative to the shell surface

all taper thickness were modeled as tapers.

See figure 9 which is a computer-profile plot with the various section thickness noted.

Loadings

The following loading cases were run:

Case 1. Gate Valve Closed

Case 2. Gate Valve Closed with transient Temp. dist. (with heat up time of 4 Hr.)

Case 1 Gate Valve Closed.

For this loading configuration the following loads were applied to the model: (see fig 11)

$P_1 = 119$ PSIa

$P_2 = 0$ PSIa

$P_3 = 0$ PSIa

$LG = PR/Z = 119 \times 84.0 / Z = 4998$ lbs/in

Case 2 Gate Valve Closed w/
Transient Temperature distribution.

For this loading case the following loads were applied to the model:
(See figure 11)

P_1 = 119. psia
P_2 = 0. psia
P_3 = 0. psia
LG = $P_1 R/2$ = 119 x 84.0/2 = 4998 lbs/in.

The transient temperature distributions vs. joint locations are shown on the next page. See figure 10 to find the relative joint location with respect to the model.

also, see figure 7c.

Transient - Gate Valve Closed
$t = 4.0$ Hours

JOINT	T-TREF °R	α(T-TREF)
1	0.	.0
3	0.	.0
4	55.	.000293
6	347.	.00185
7	355.	.001892
10	347.	.00185
14	124.	.000661
17	8.	.000043
20	5.	.000027
32	47.	.000251
35	82.	.000437
38	140.	.000746
41	205.	.001093
45	280.	.001492
46	223.	.00189
66	300.	.001599
67	355.	.001892
78	300.	.001599
79	300.	.001599
93	323.	.001722

Tref = 200. °R
$\alpha = .533 \times 10^{-5}$ IN/IN°F
or Tref = -260°F

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The merdian and circumferential thermal strains (θ_s, θ_ϕ) are defined to be

$\theta_s = \int_{t_0}^{t} \alpha_s \, dt \quad \theta_\phi = \int_{t_0}^{t} \alpha_\phi \, dt.$

$\alpha = \alpha_s = \alpha_\phi = \text{Constant} \quad \therefore, \theta_s - \theta_\phi = \alpha T$

Stress and buckling results.

Note: a definition on how to read the following data.

Figure 8 is a reference surface plot of the model indicating the +s and z direction. The inside surface shall be defined as the reference surface and The out side surface as measured in the z direction away from the reference Surface.

See figure 9, The inside surface shall be the continious line with "+" indicated on it. The out side surface will then be the continious line next to it.

FIGure 10 is a plot showing the node locations the double numbers indicates the end then the begining of a sub segment, The Triple numbers a branch point.

The integer numbers shown on figure 11 Corespond To the Integers shown on figure 12.

Here they indicate the different regions of the model relative to The Continious meridional distance.

Results load Case 1

Valve Closed

From Computer run JGR and Shown in figures 12, 13, 14 are stress plots of σ_{Hoop} and $\sigma_{meridian}$ vs. meridian distance.

Figure 12. is a numerical average of the inside and outside surface stresses in the circumferential and meridian directions.

Figure 13. outside surface stresses in the circumferential and meridian directions.

Figure 14. inside surface stresses in the circumferential and meridian directions.

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Hydr test Conditions

The hydo test pressure was assumed to be the max. pressure at the bottom of the tunnel for the region under consideration.

$$P_H = 1.5 \times 119 + \frac{62.4}{144}\left(\frac{41'}{2} + \frac{28}{2}\right) = 193.45 \text{ PSI}$$

Stress scale factor = 193.45/119 = 1.626

The max. general membrane stress ⊥ to weld is smaller of.

$P_m < 0.8 \times 52.5 = 42.0 \text{ KSI}$

or

$P_m < .5 \times 95.0 = 47.5 \text{ KSI}$

$S = 1.626 \times 20.3 = 33 \text{ KSI}$

$33.0 < 42.0 \text{ KSI}$

This region meets the stress evaluation criteria for hydo test conditions.

Bifurcation buckling of Bulkhead.

There were several run made to determine the critical load factor for the Bulkhead region. Here the prestressed "valve closed" condition was run. This loading condition generated the maximum pressure differential across the bulkhead (P= 119, PSIG).

EARLY ATTEMPTS TO extract an eigen value generated negative eigen values bifurcating on the shell.

A stepwise procedure of shifting the eigen value was accepted untill a positive eigenvalue was generated.

The following table summarizes the eigenvalue solution. Which indicates that the minimum critical load factor of 15,88 when applied To the 119.0 PSI eternial pressure would require a pressure of 1889.72 PSI before buckling would accure.

BY_____ DATE_____ SUBJECT_____ SHEET NO. 73 OF_____

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Membrane stress (Intensity)

Primary local membrane stress intensity

$\sigma_1 = 11.50$ KSI

$\sigma_2 = -5.0$ KSI

$\sigma_3 = -.06$ KSI

$S_{12} = 11.50 - (-5.0) = 16.5$ KSI

$S_{23} = -5.0 - (-.06) = -4.94$ KSI

$S_{31} = -.06 - 11.50 = -11.56$ KSI

$S = |16.5| = 16.5$ KSI

P_M 16.5 KSI < S_M = 317 KSI OK

Since the stress intensity is < S_M (31.7 KSI)
The stress intensity meets the criteria for general membrane stress intensity.

General membrane stress intensity

$S = 20.3$ KSI

20.3 KSI < 23.7 KSI

This region meets the stress evaluation criteria for general membrane stress.

Primary plus secondary stress intensity

inside surface

$\sigma_1 = 16.0$ KSI

$\sigma_2 = 12.0$ KSI

$\sigma_3 = -.119$ KSI

$S_{12} = 16 - 12 = 4.0$ KSI

$S_{23} = 12.0 - (-.119) = 12.119$ KSI

$S_{31} = -.119 - 16.0 = -16.119$ KSI

$S = |-16.119| = 16.119$ KSI

$P_L + P_b + Q < \sigma_{yp}$ (weld) $= 52.5$ KSI

16.119 KSI < 52.5 KSI OK

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Outside surface

$\sigma_1 = -23.0$ KSI

$\sigma_2 = 6.5$ KSI

$\sigma_3 = 0$ KSI

$S_{12} = -23.0 - (6.5) = -29.5$ KSI

$S_{23} = 6.5 - 0 = 6.5$ KSI

$S_{31} = 0 - (-23.00) = 23.0$ KSI

$S = |-29.5| = 29.5$ KSI

$P_L + P_b + Q = 29.5 < \sigma_{yp}$ (Weld) $= 52.5$ OK

the primary plus secondary stress intensity meets the stress evaluation criteria.

Value Cross loading Condition.
Bifurcation Buckling Load factors.

Harmonic Number	λ	Location	Mode
2	15.88	Bulkhead	14
3	16.90	"	14
4	20.22	"	15,16
5	22.91		18,19
6	23.72		30,31
7	23.51		30,31
8	23.66		30,31
9	24.25		30,31
10	25.30		30.31

A hand calculation for a shericaL Shell with the same geometry and properties yields a critical pressure of 2372. psi. ($\lambda = P_{cr}/P = 19.9$)

from this value a load factor can be determined to verify that the solutions obtained from this computer analysis are in good agreement with what would be expected.

Also, along with the linear analysis a non linear analysis was performed. With a load factor of 15 on a prestressed structure. using a 119 psi pressure, an estimated load factor of $\lambda_c = 16.2$ was found. which is in very good agreement with the linear bifurcation buckling analysis.

BY _____ DATE _____
CHKD. BY _____ DATE _____

SUBJECT _____

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JOB NO. _____

RESULTS load case 2

Gate Valve Closed W/ TRAN TEMP DIST.
(4 Hour WARM UP time)

From Computer run IYI and shown in figures 15, 16, 17 are stress plots of σ_{HOOP} and $\sigma_{meridian}$ vs. meridian distance.

Figure 15 is a numerical average of the inside and outside surface stresses in the circumferential and meridian directions.

Figure 16 outside surface stresses in the circumferential and meridian directions.

Figure 17 inside surface stresses in the circumferential and meridian directions.

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BY_____ DATE_____ SUBJECT_____ SHEET NO. 80 OF_____

CHKD. BY_____ DATE_____ JOB NO._____

General Thermal Stress

$\sigma_1 = -38.5$ KSI

$\sigma_2 = -5.0$ KSI

$\sigma_3 = 0$ KSI

$S_{12} = -38.5 - (-5.0) = -33.5$ KSI

$S_{23} = -5.0 - 0 = -5.0$ KSI

$S_{31} = 0 - (-38.5) = 38.5$ KSI

$P_L + P_b + Q = |38.5| = 38.5$ KSI

$38.5 < S_{yr}$ (weld) $= 52.5$ KSI OK

Membrane stress (intensity)
(away from hatch opening)

Primary local membrane stress intensity

$\sigma_1 = 12.5$ KSI

$\sigma_2 = -5.0$ KSI

$\sigma_3 = -.119$ KSI

$S_{12} = 12.5 (-)(-5.0) = -17.5$ KSI

$S_{23} = -5.0 -(-.119) = -4.881$ KSI

$S_{31} = -.119 - 12.5 = -12.619$ KSI

$S = |-17.5| = 17.5$ KSI

$P_M = 17.5 \leq 31.7$ KSI

Since the stress intensity is $< S_M$ (31.7 KS.) the stress intensity meets the criteria for general membrane stress intensity.

General Membrane stress

$S = 20.3$ KSI

$20.3 \leq 23.7$ KSI

This region meets the stress evaluation criteria for general membrane stress.

BY_____ DATE_____ SUBJECT_____ SHEET NO. 82 OF_____

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Primary plus secondary stress intens.

Inside surface

$\sigma_1 = -38.31$ KSI

$\sigma_2 = 6.706$ KSI

$\sigma_3 = -.119$ KSI

$S_{12} = -38.31 - 6.71 = -45.02$ KSI

$S_{23} = 6.71 - (-.119) = 6.829$ KSI

$S_{31} = -.119 - (-38.71) = +38.191$ KSI

$S = |-45.02| = 45.02$ KSI

$P_L + P_b + Q = 45.02 < \sigma_{yp}(\text{Weld}) = 52.50$

Out side surface

$\sigma_1 = -44.19$ KSI

$\sigma_2 = -2.30$ KSI

$\sigma_3 = 0$ KSI

$S_{12} = -44.19 - (-2.30) = -41.89$ KSI

$S_{23} = -2.30 - 0 = -2.30$ KSI

$S_{31} = 0 - (-44.19) = 44.19$ KSI

$S: |44.19| = 44.19$ KSI

$P_L + P_b + Q = 44.94 < S_{yp}(\text{Weld}) = 52.5$ KSI ok

the primary plus secondary stress intensity meet the stress evaluation criteria.

The following table summarizes the eigen value solution. which indicates that the minimum critical load factor of 14.80 when applied to the 119.0 psi external pressure and temp. loads would require a pressure of 1761.2 psi before buckling would accure

C 2

Valve Closed Transient temperature critical load factor.

Buckling analysis

Harmonic Number	λ	Location	Node
2	-10.44	Bulkhead	46
3	-9.97	"	46
4	-9.79	"	46
5	-15.05	"	29
6	+14.80	"	29
7	15.10	"	29
8	15.98	"	30, 31
9	17.64	"	30, 31
10	20.80	"	30, 31

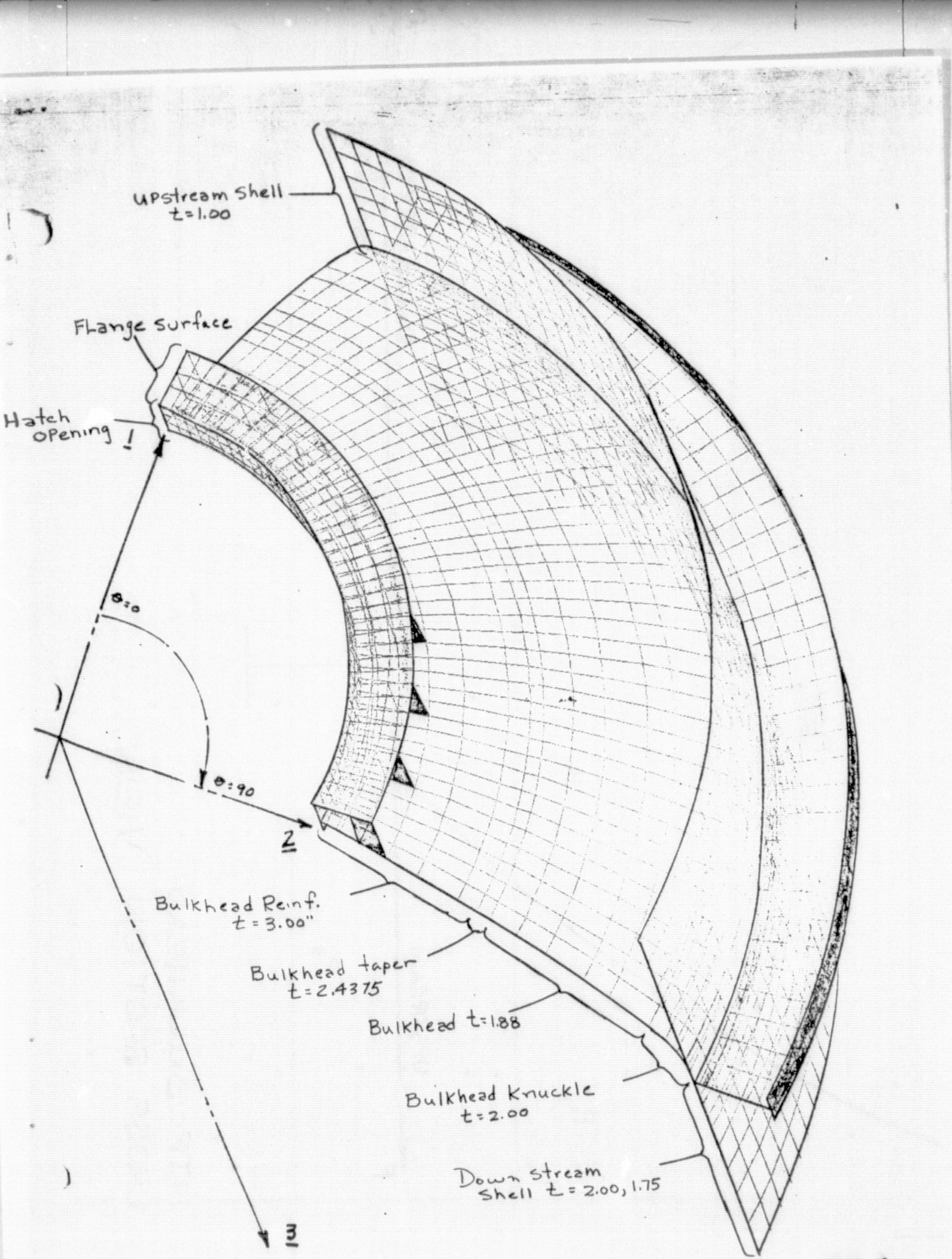

FIG. 1.

NTS BULKHEAD

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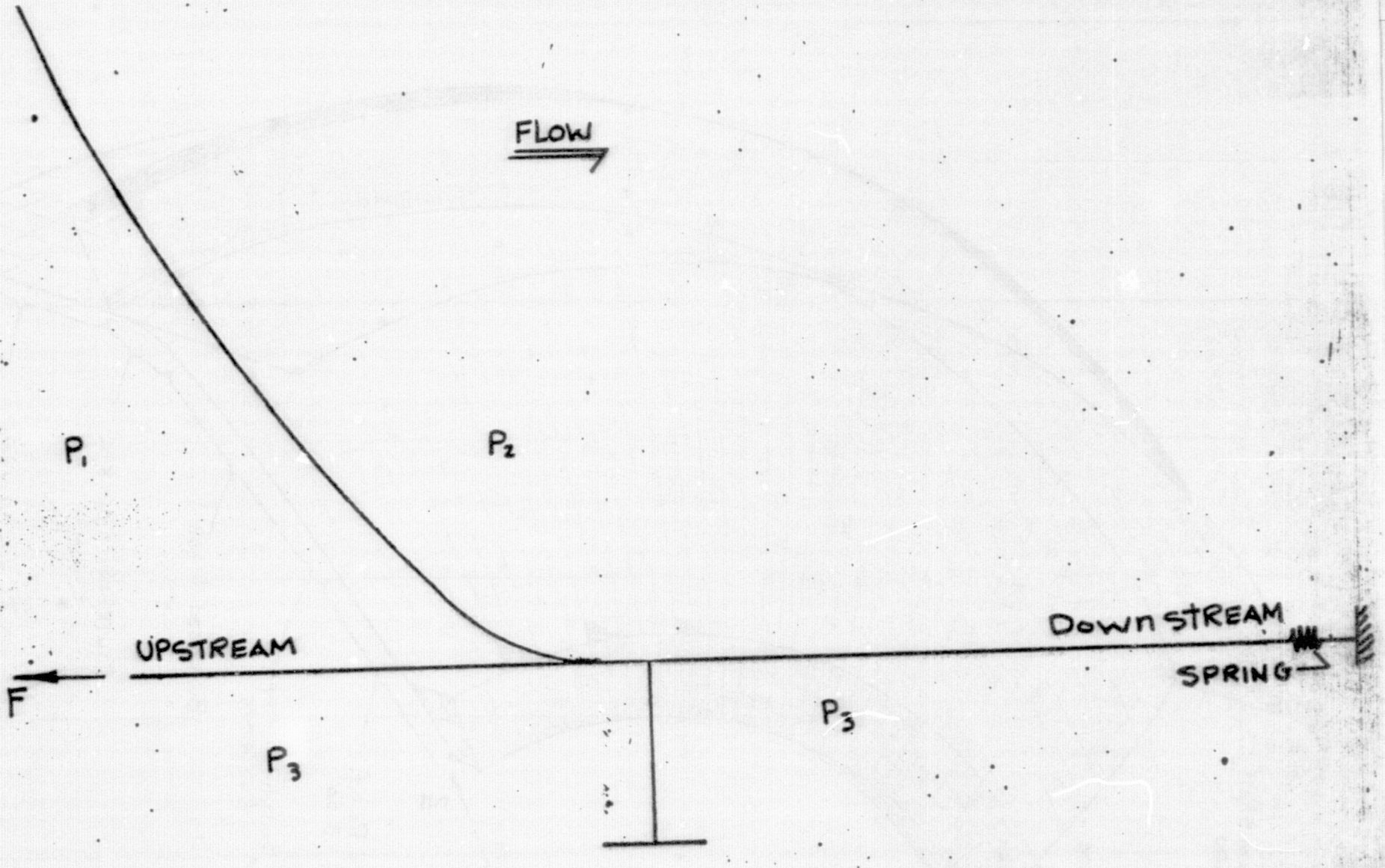
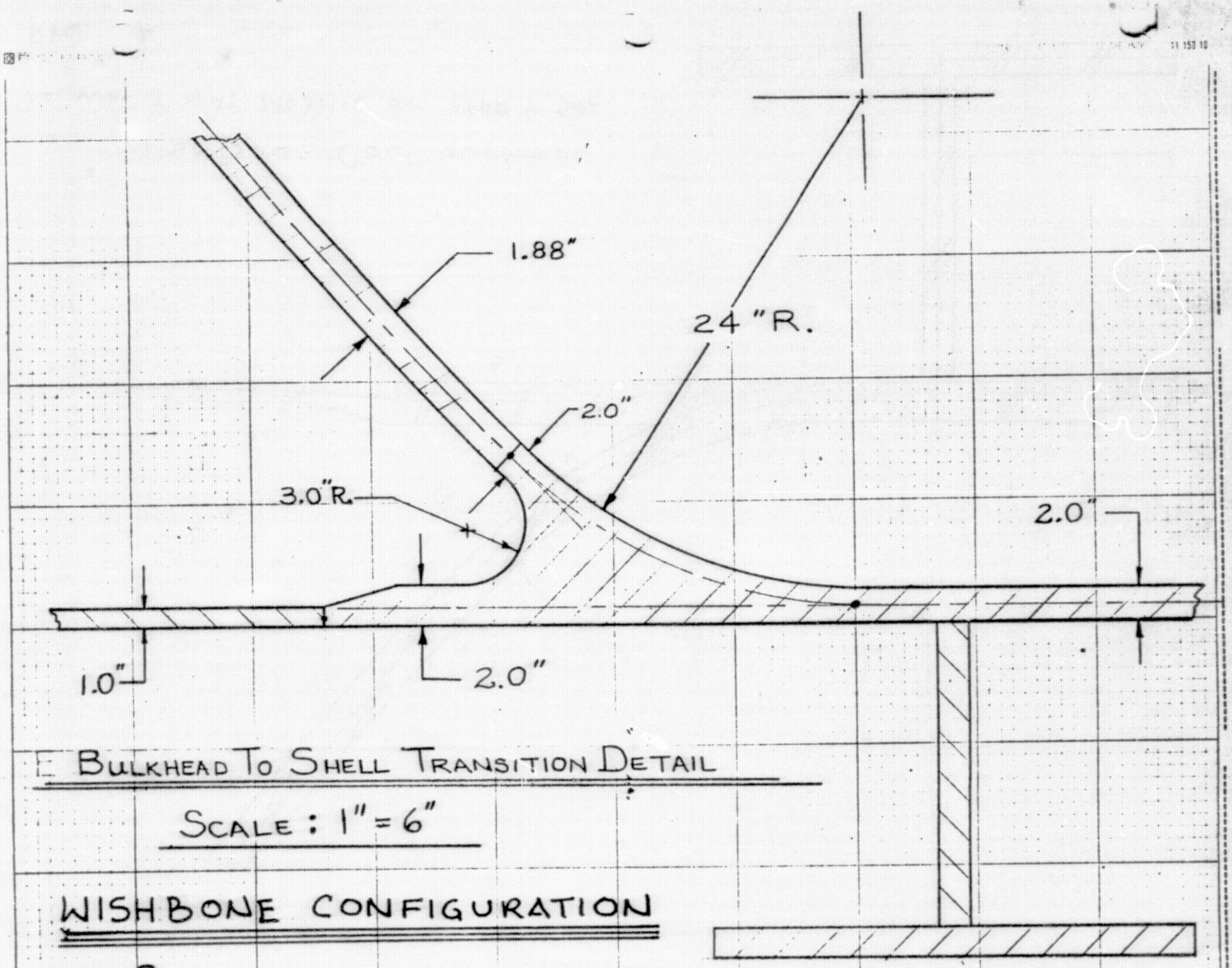


NTF BULKHEAD
CROSS SECTION. VIEW



E BULKHEAD TO SHELL TRANSITION DETAIL

SCALE: 1" = 6"

WISHBONE CONFIGURATION

FIG. 3

BY John Taylor DATE 7-1-76 SUBJECT

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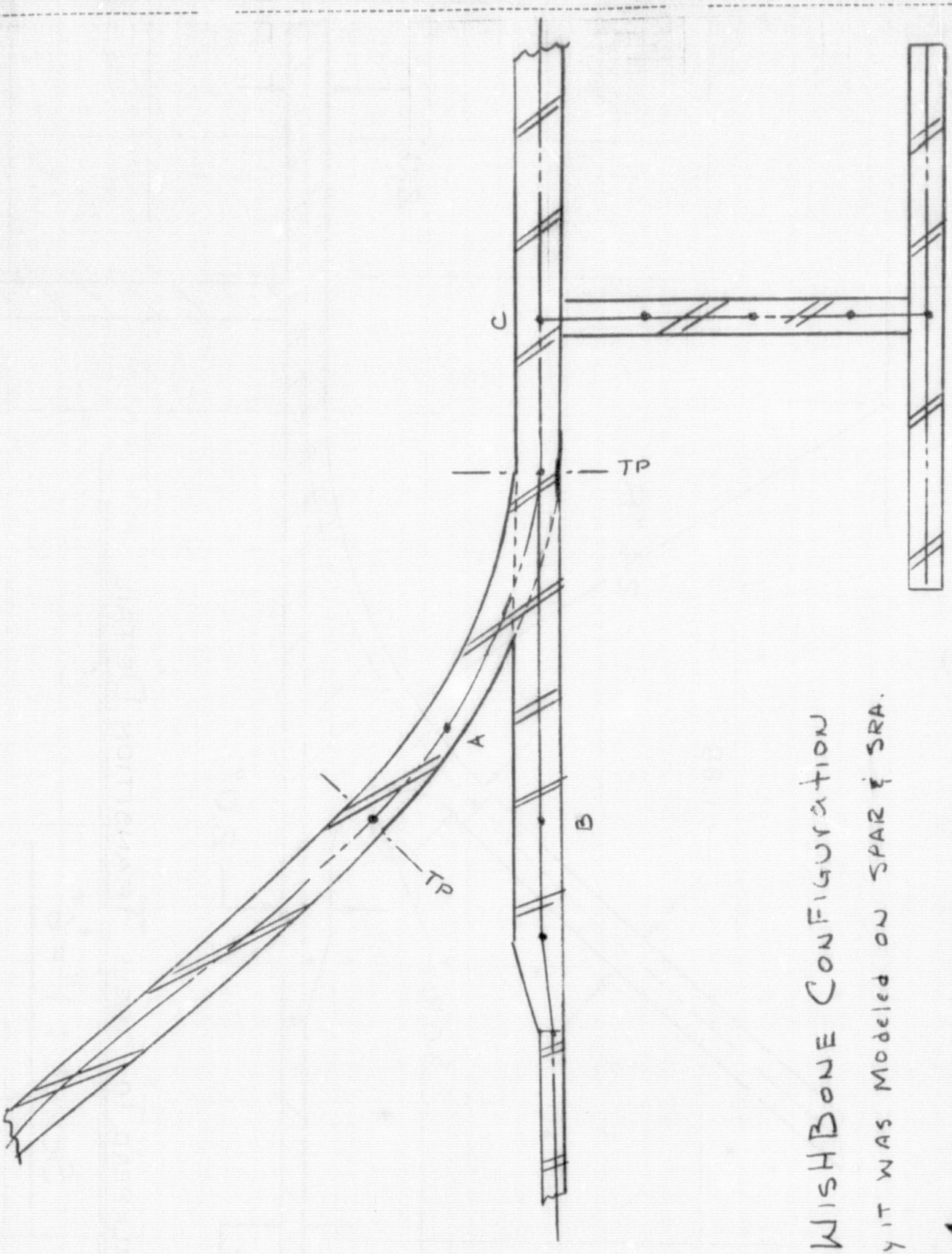

WISHBONE CONFIGURATION
The Way it was Modeled on SPAR & SRA.

FIG. 4

BY _____ DATE _____ SUBJECT _____ SHEET NO. _____ OF _____

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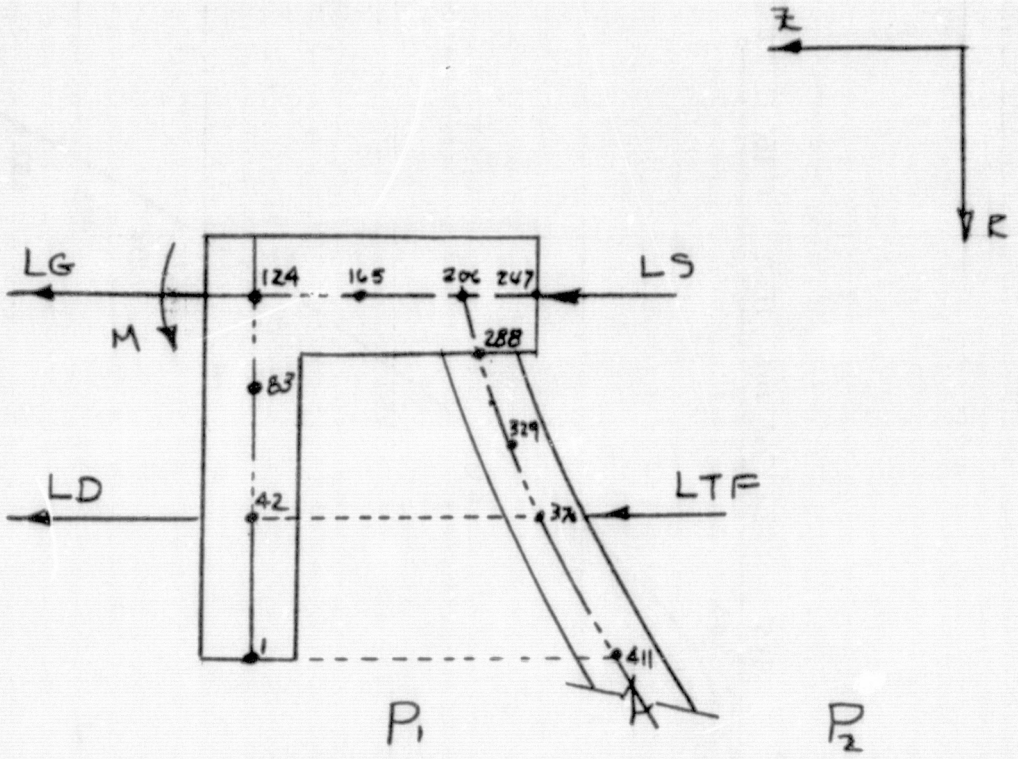
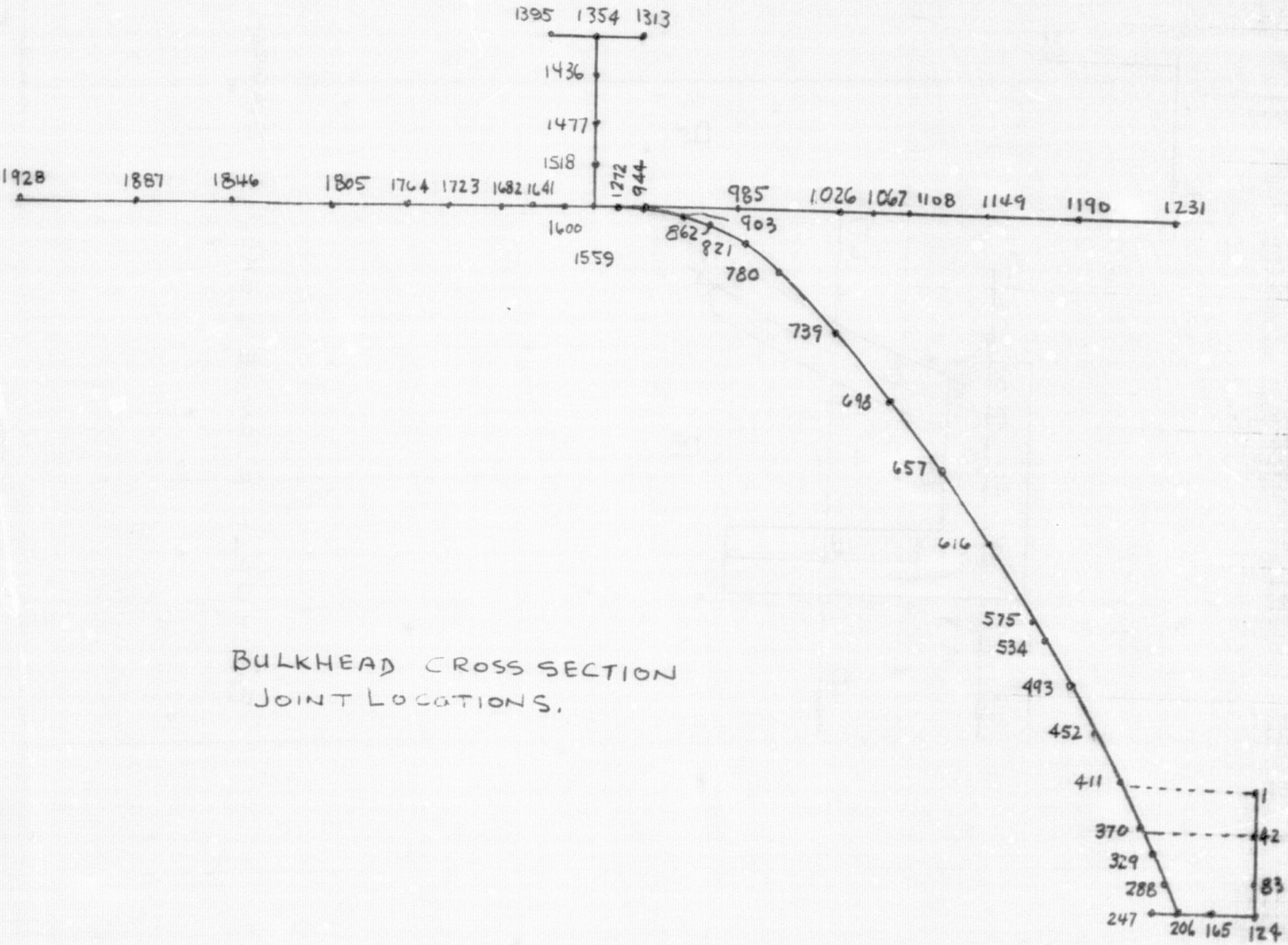


BULKHEAD FLANGE LOADING DIAGRAM

FIG. 5



BULKHEAD CROSS SECTION
JOINT LOCATIONS.

FIG 6

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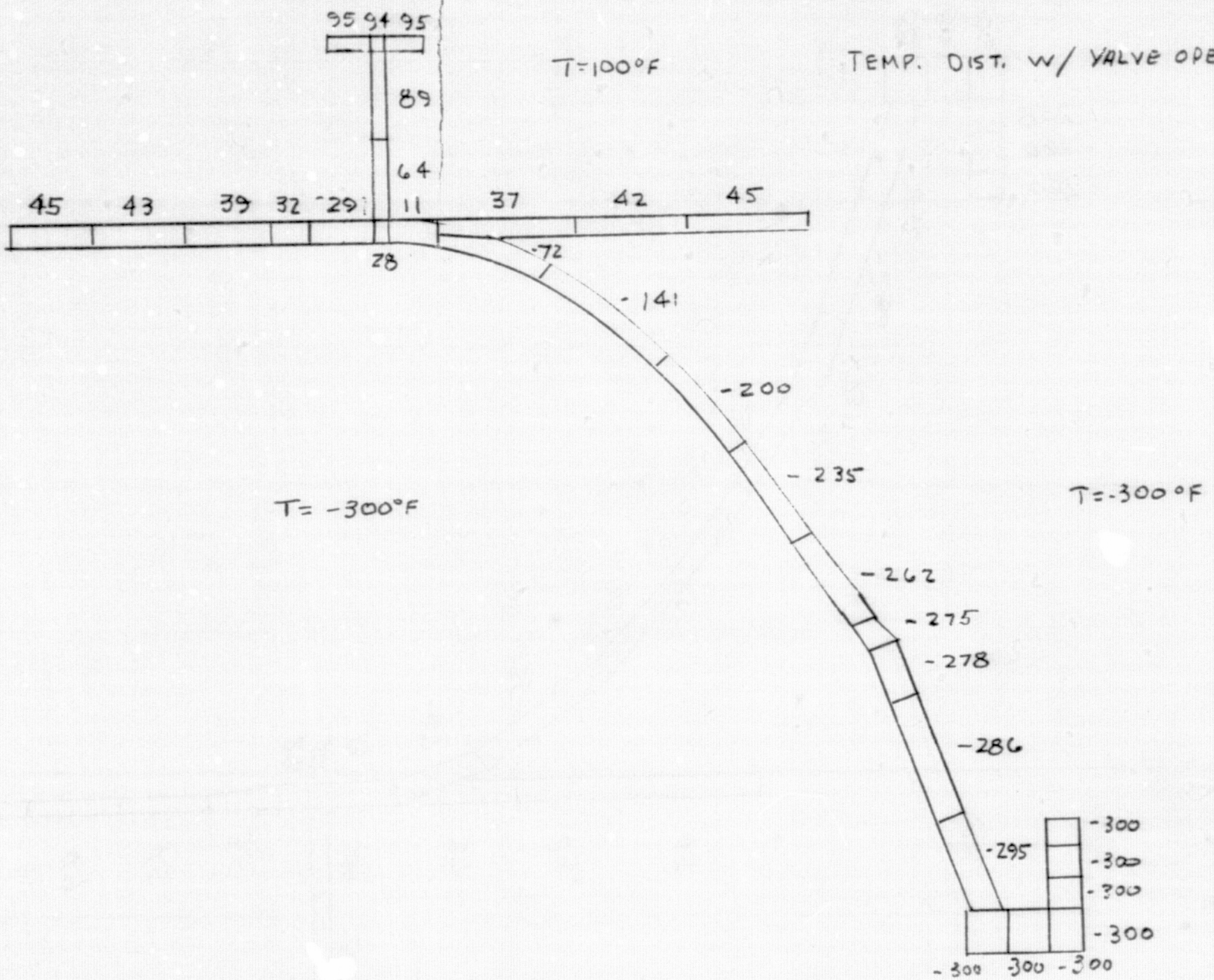
CHKD. BY _____ DATE _____ JOB NO. _____



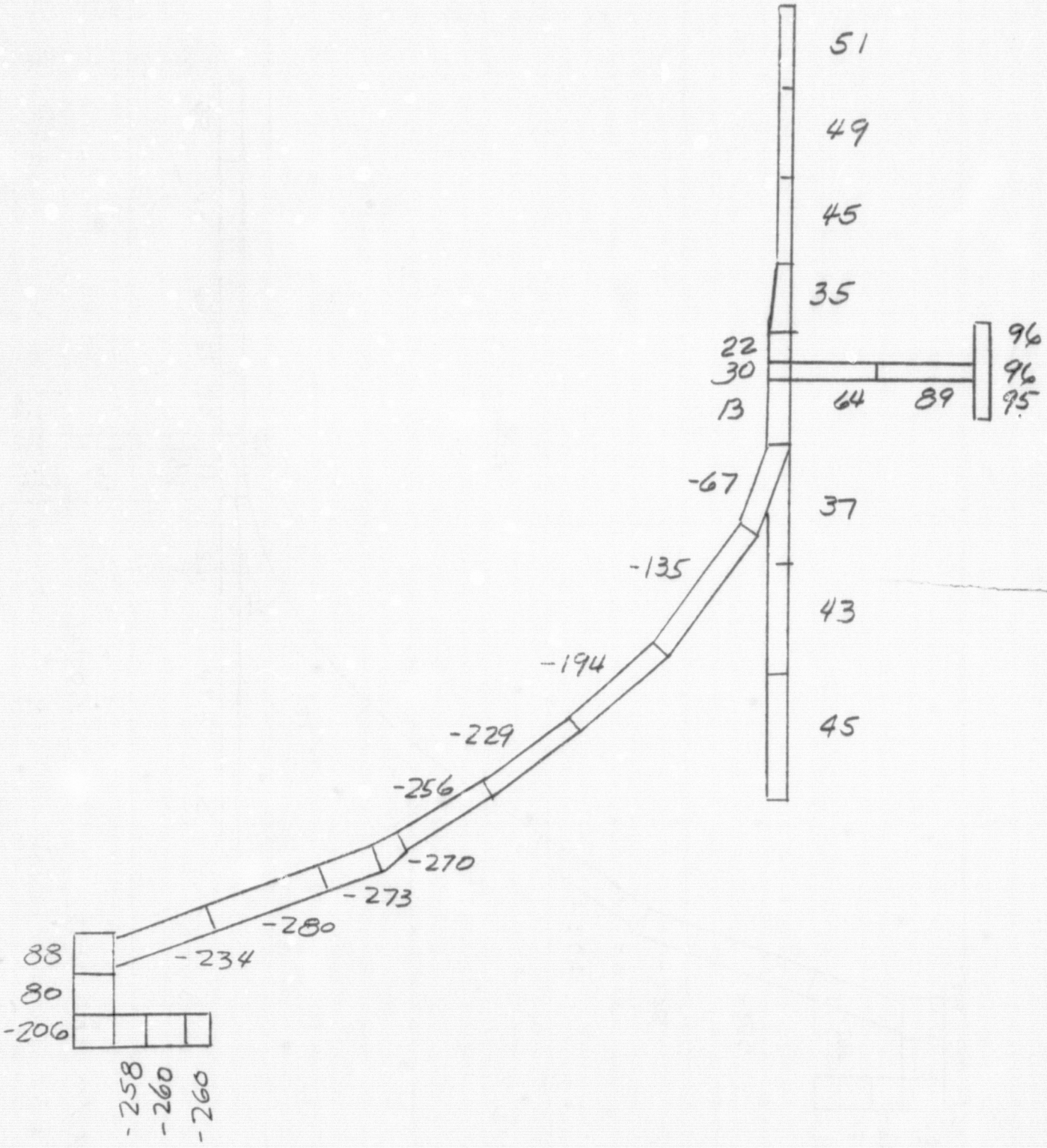
TEMP. DIST. W/ VALVE OPEN

FIG. 7a

BY _____ DATE _____ SUBJECT _____ SHEET NO. _____ OF _____

CHKD. BY _____ DATE _____ JOB NO. _____

Heat-up time of 30 MIN.



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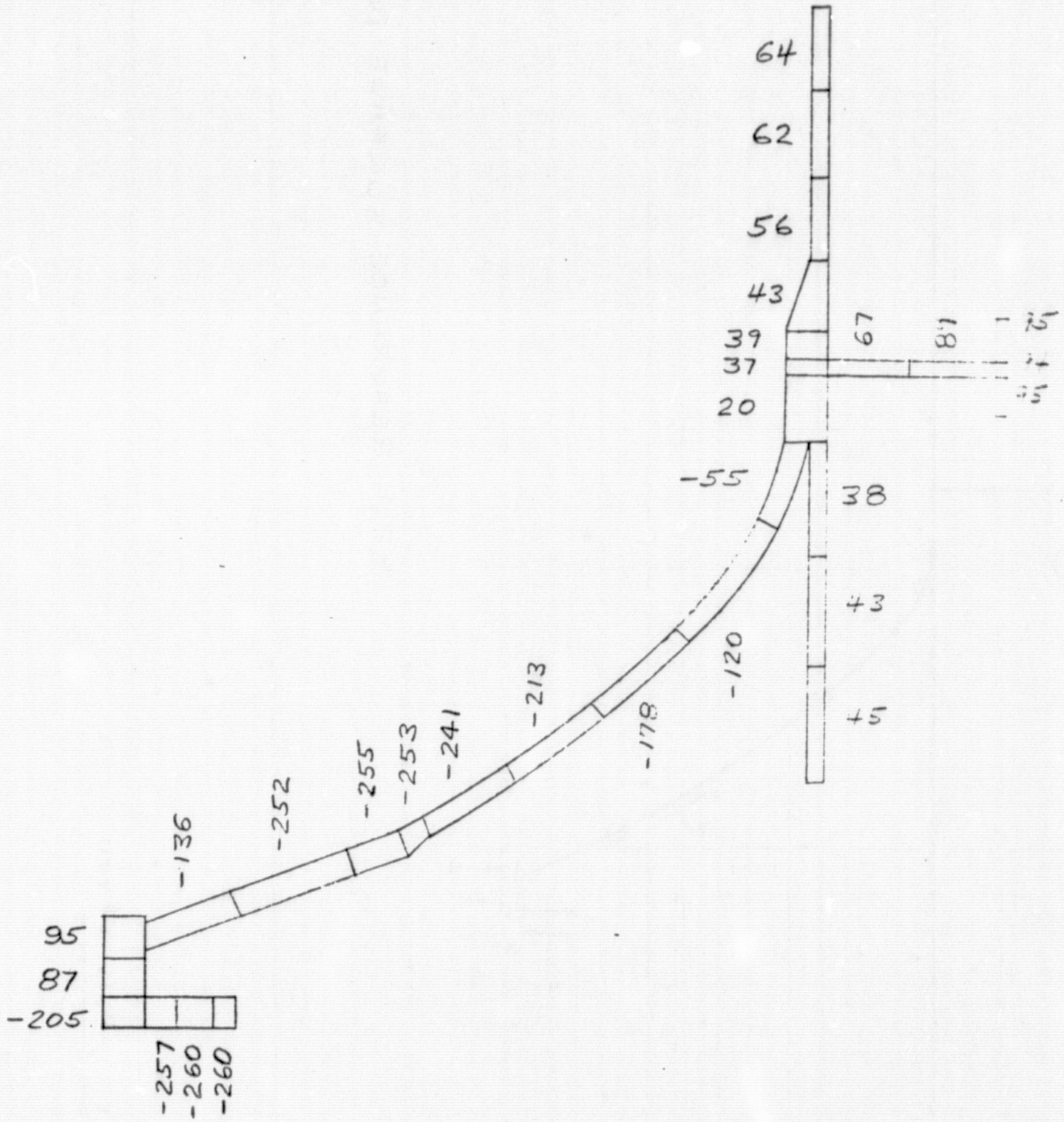
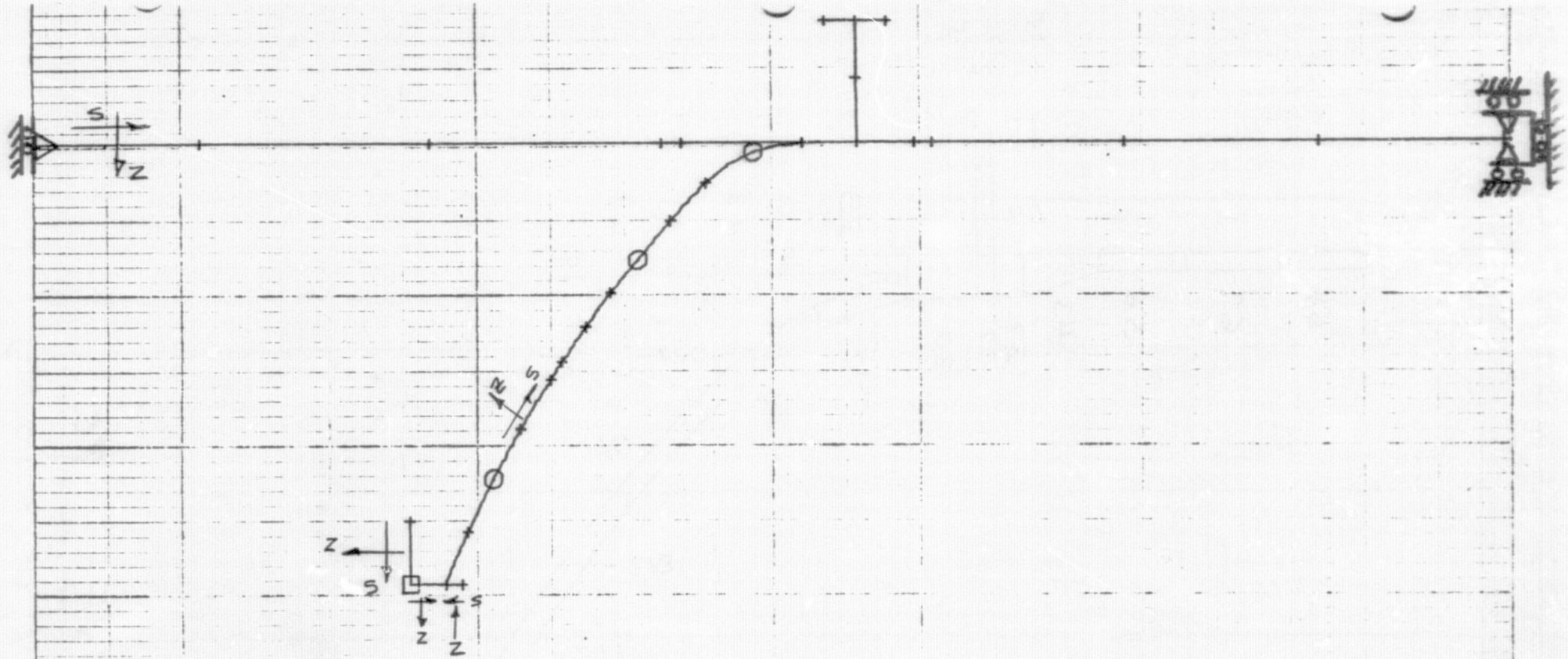
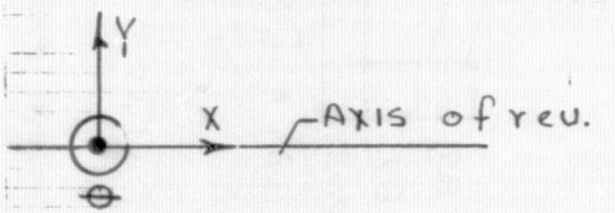


FIGURE - 7C

(HEAT UP TIME OF 4 HOURS)



SRA'S REFERANCE SURFACE DEFINATION



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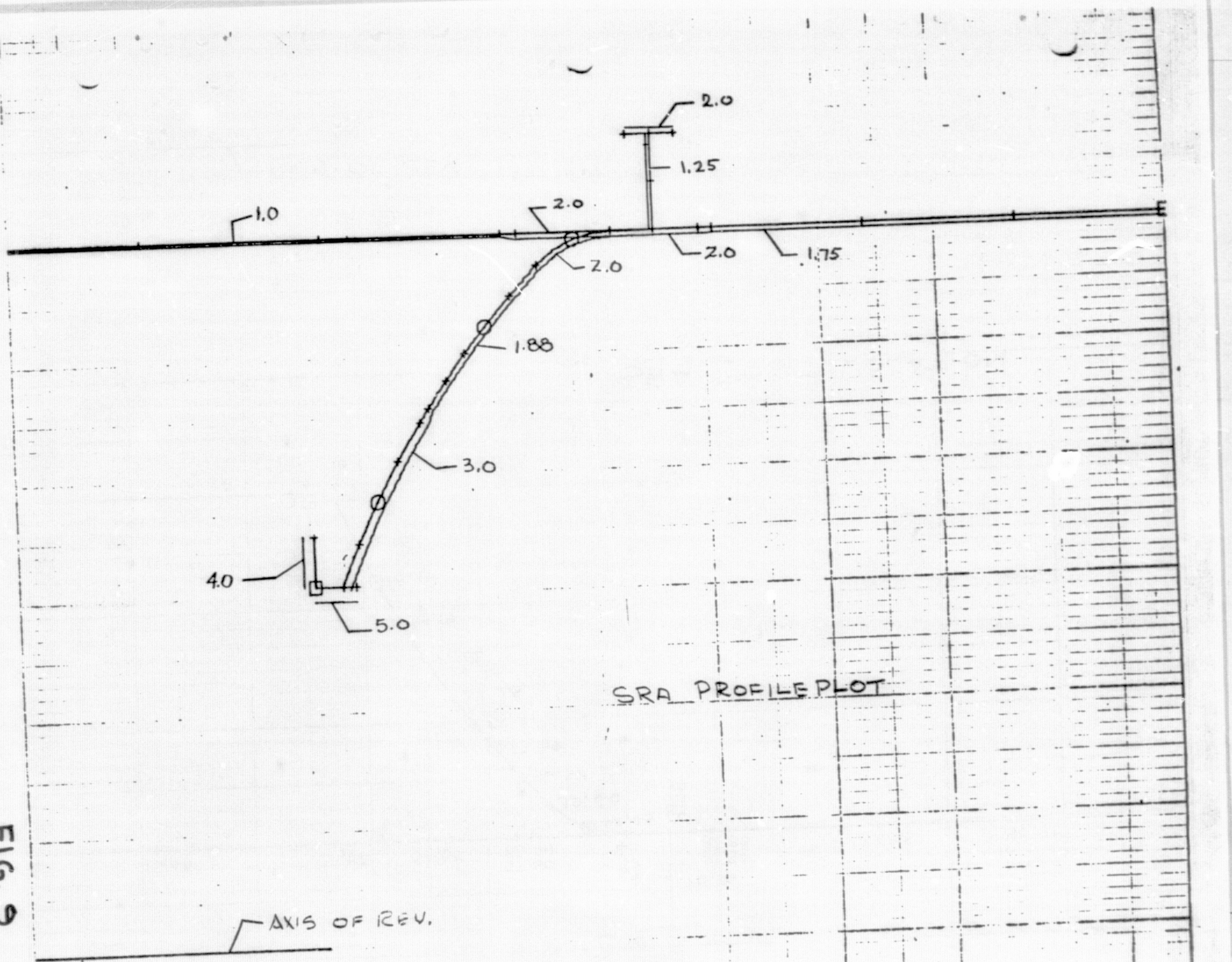
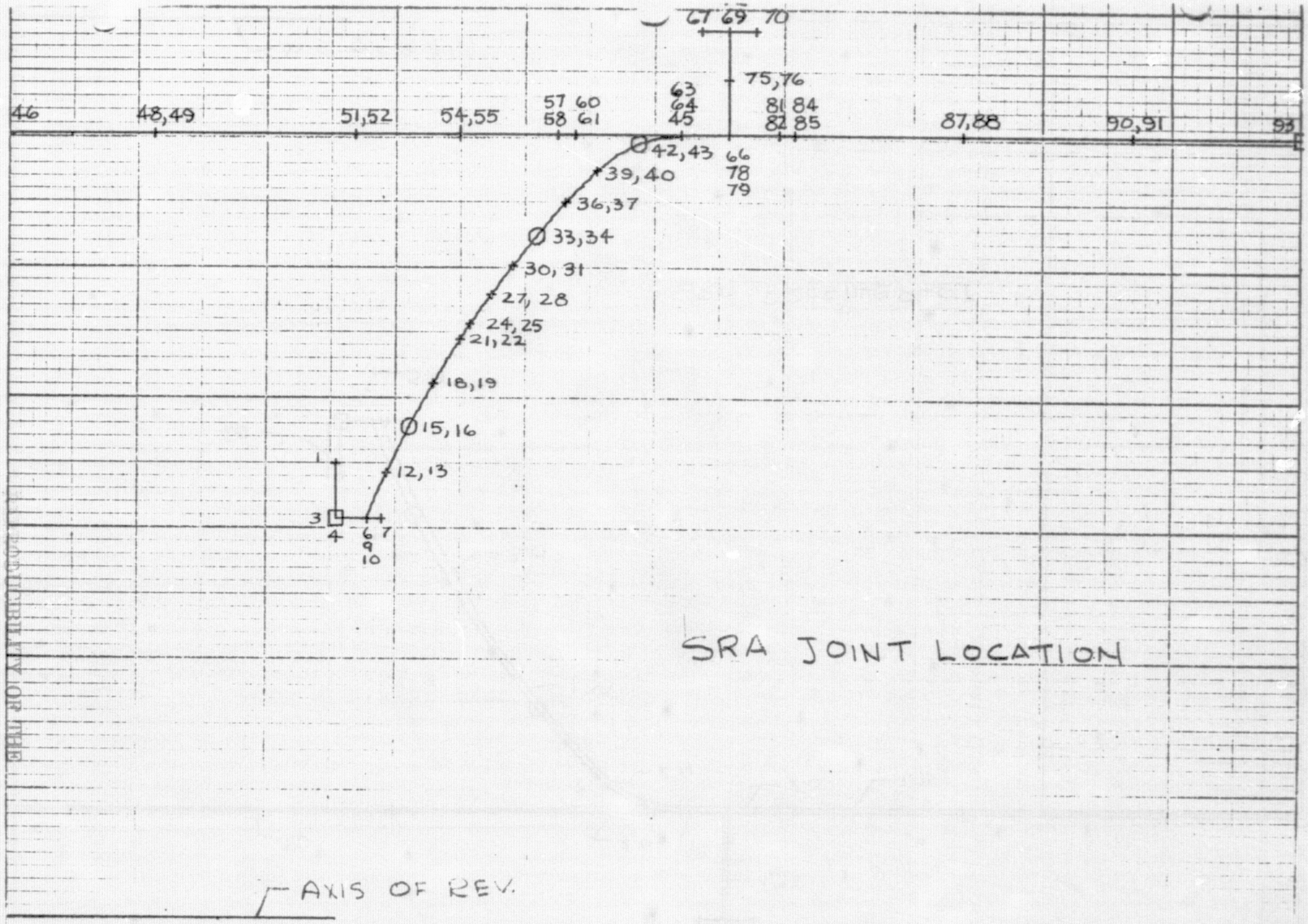


FIG. 9



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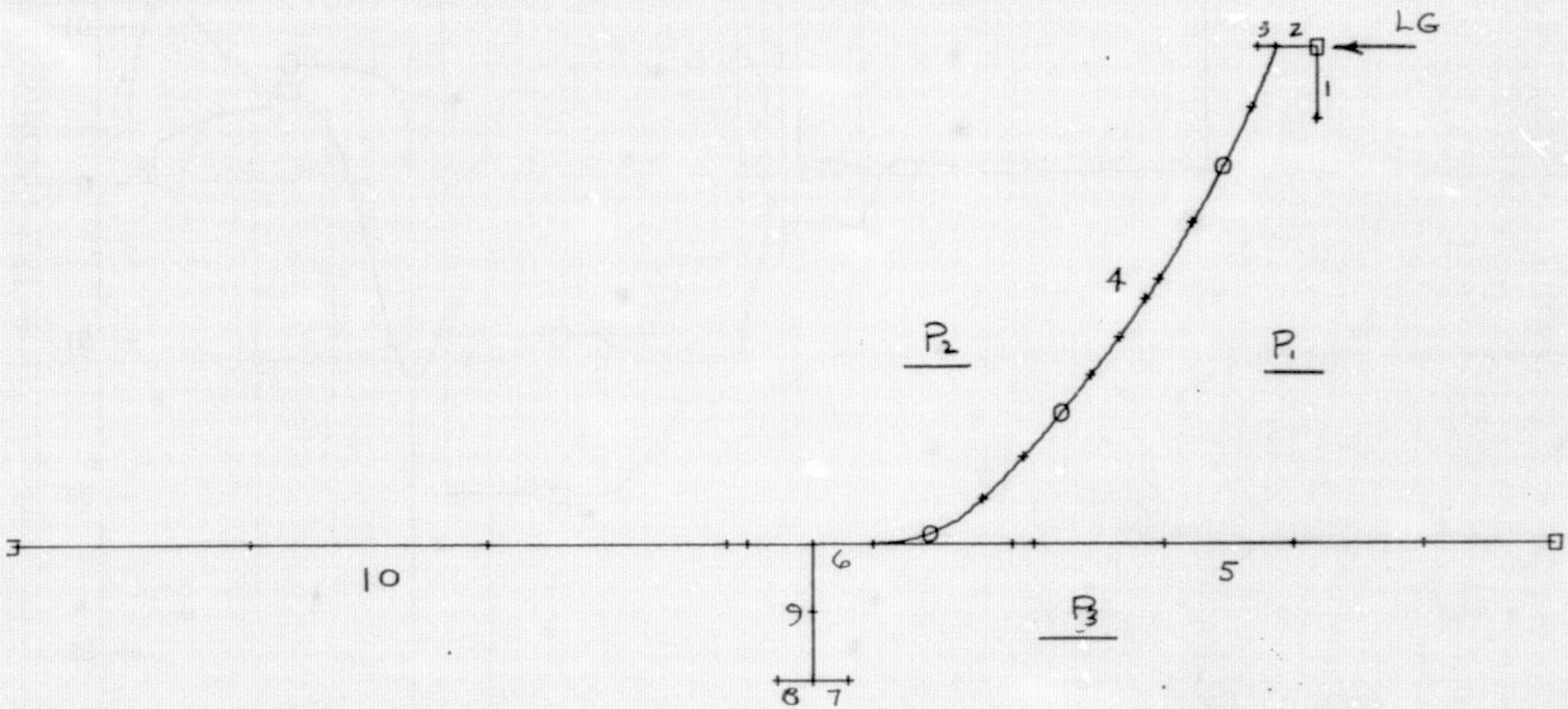
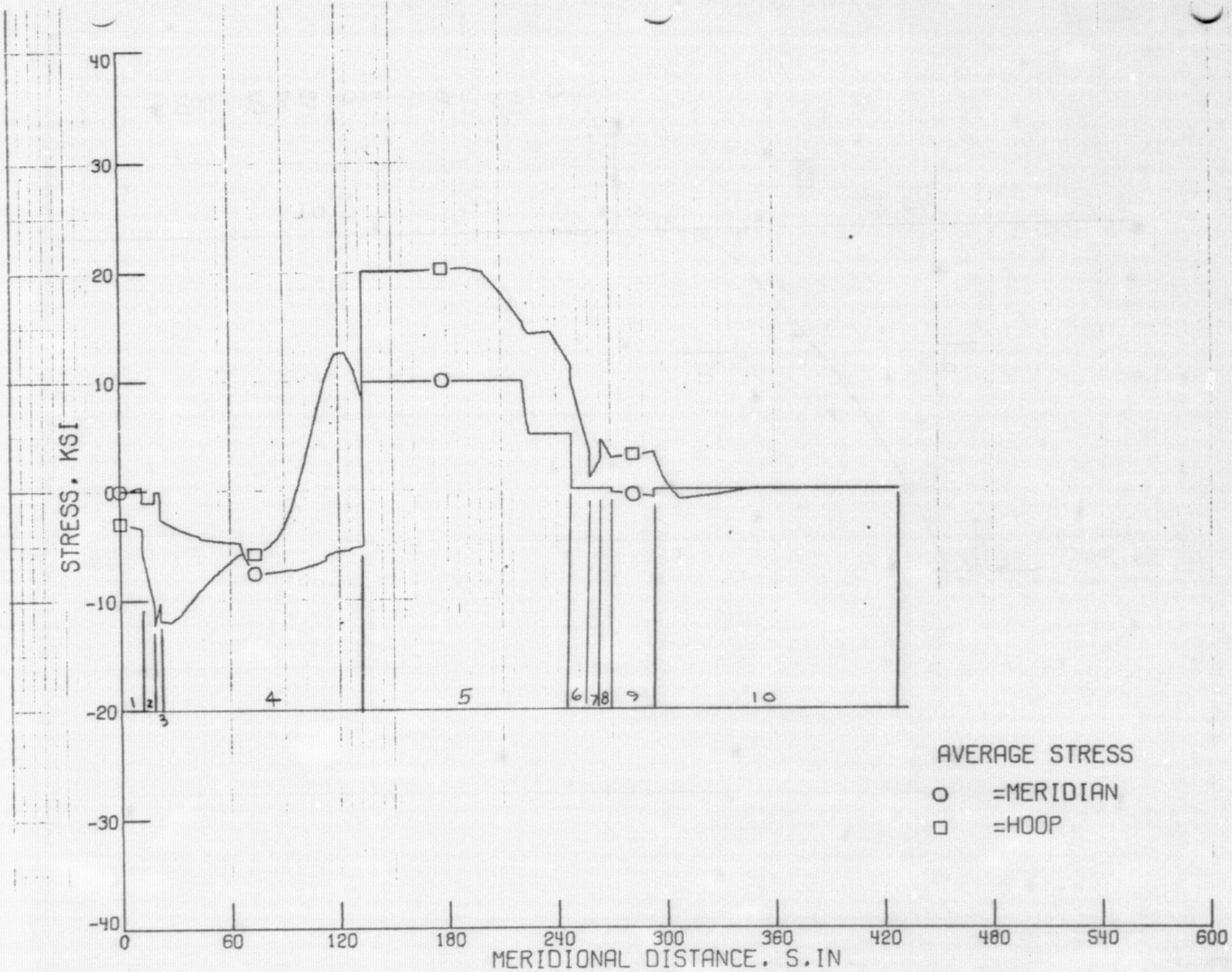
QUALITY FOR THE

NTF BULKHEAD LRC1 CONF. W/ INS. T RINGS



SRA REGION LOCATION

FIG. 11


40
30
20
10
0
-10
-20
-30
-40
STRESS. KSI
1
2
3
4
5
6
7
8
9
10
0
60
120
180
240
300
360
420
480
540
600
MERIDIONAL DISTANCE. S.IN
AVERAGE STRESS
O =MERIDIAN
□ =HOOP

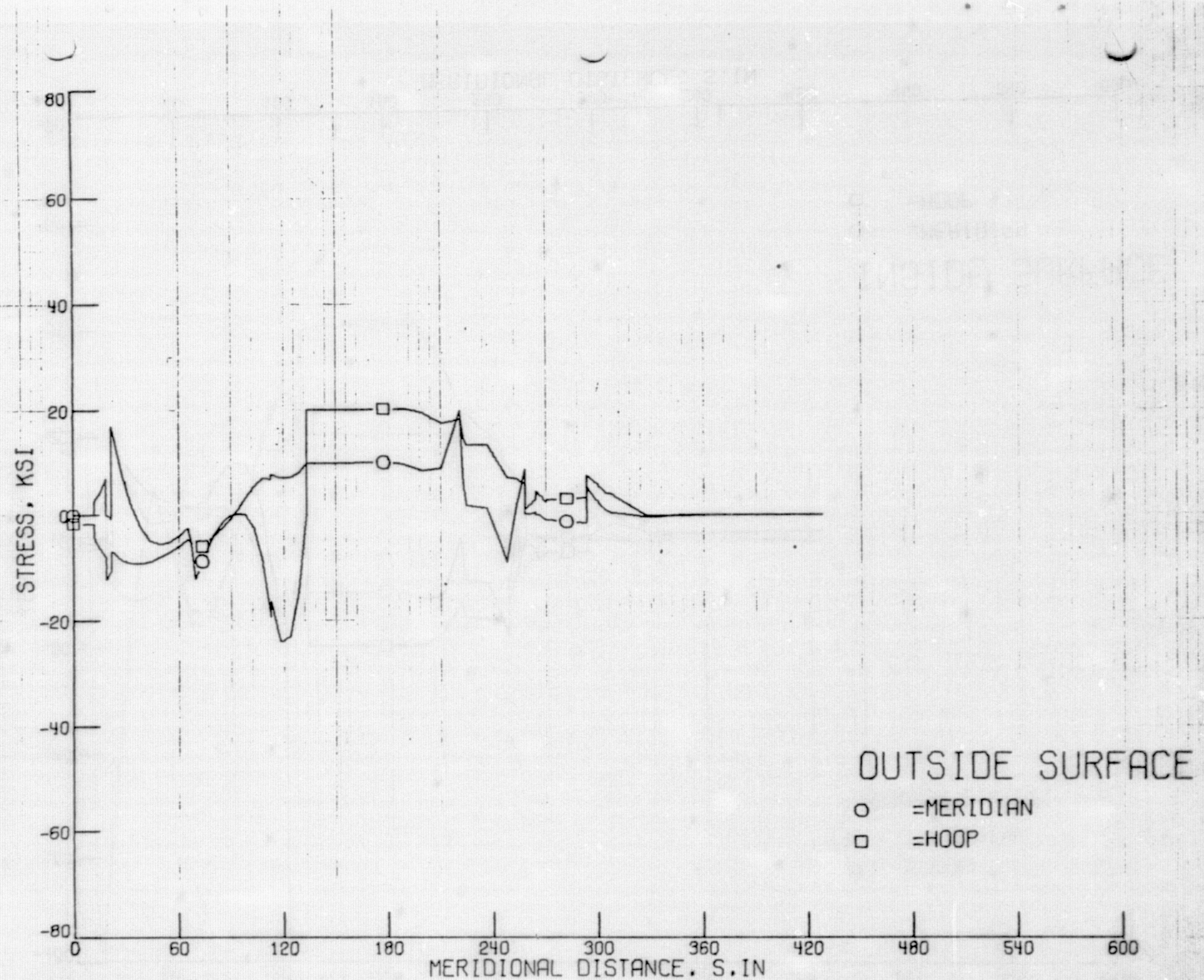

80
60
40
20
0
-20
-40
-60
-80
STRESS, KSI
0
60
120
180
240
300
360
420
480
540
600
MERIDIONAL DISTANCE. S.IN
OUTSIDE SURFACE
=MERIDIAN
=HOOP

FIG.13

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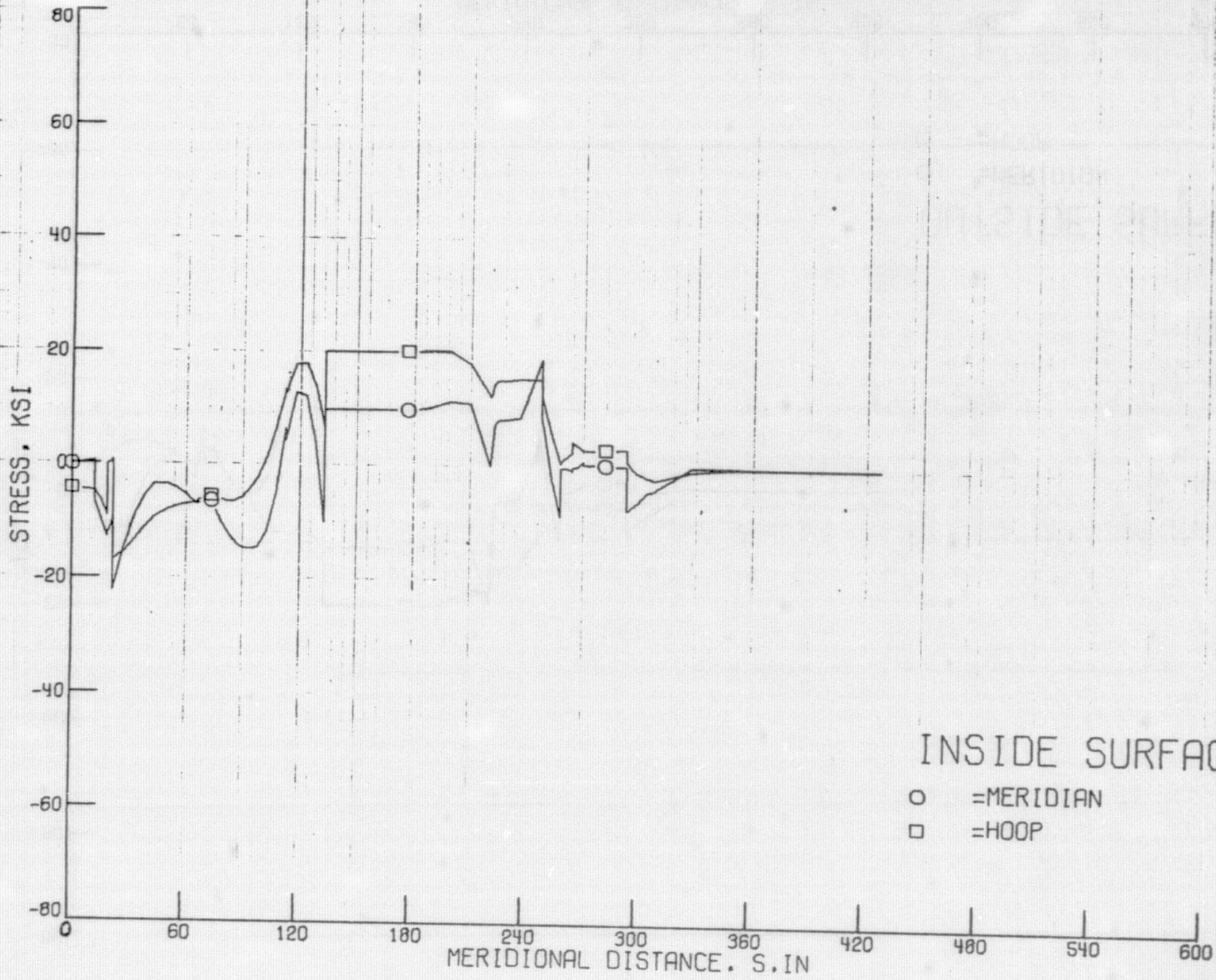


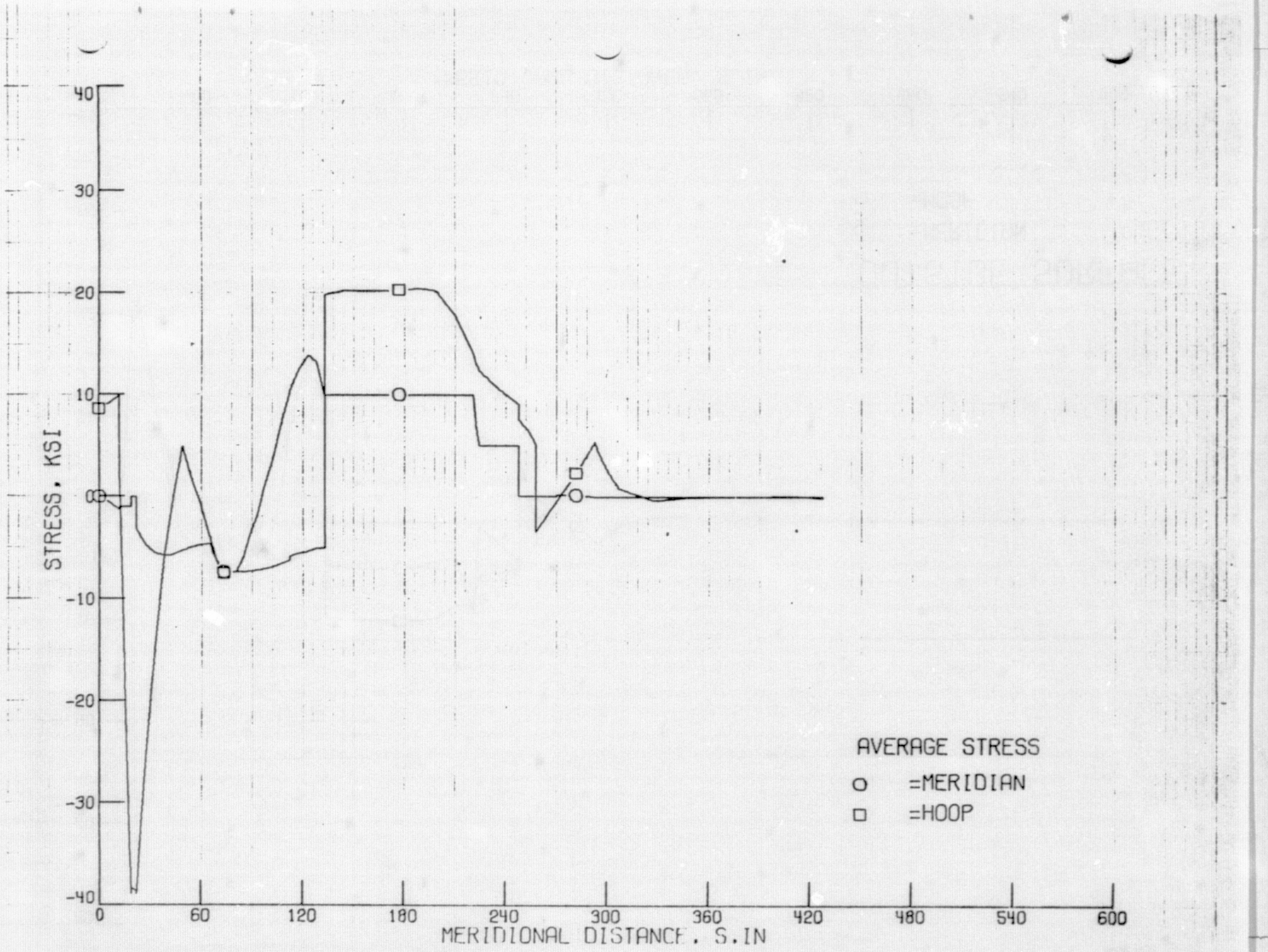
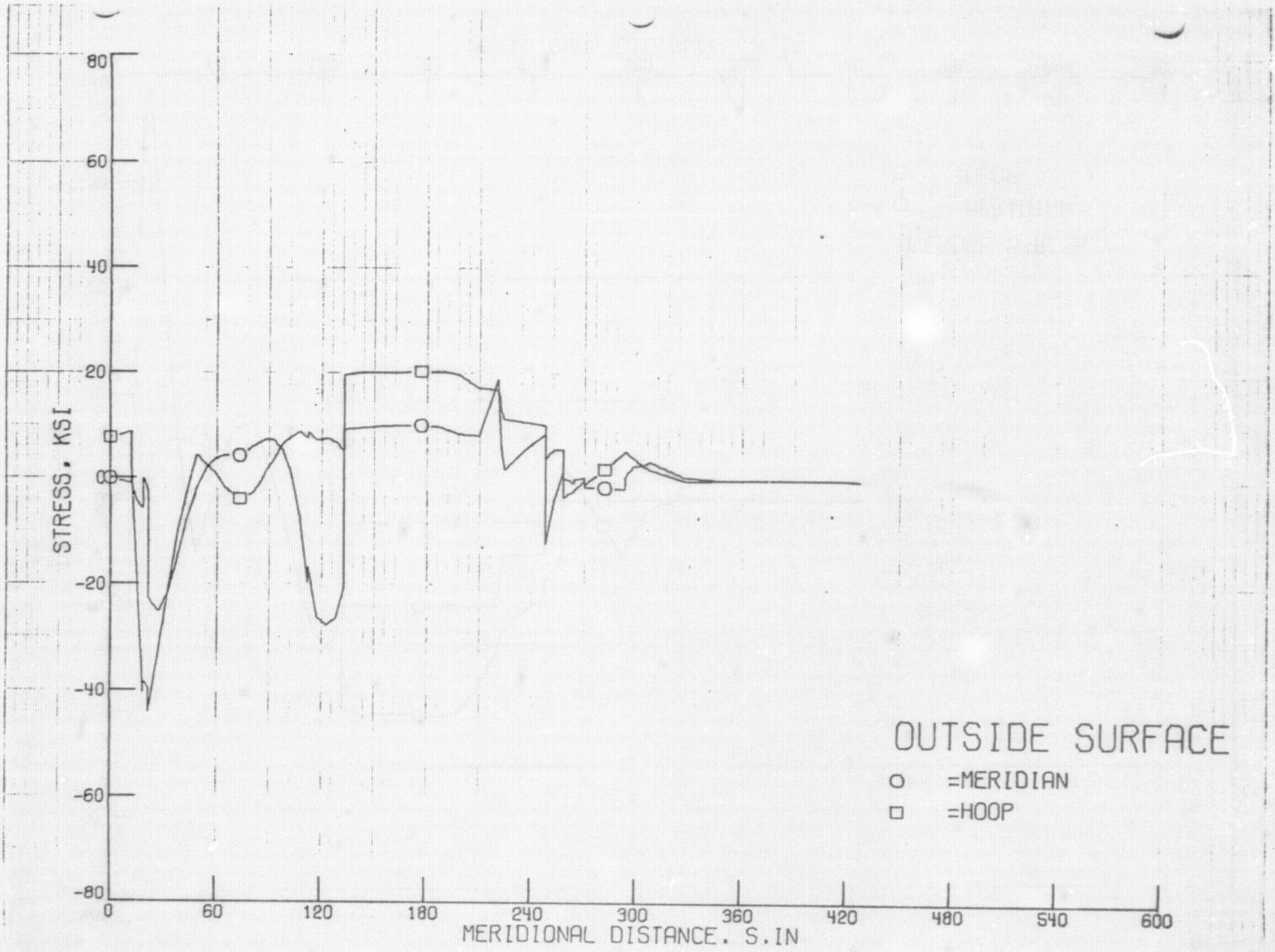

40
30
20
10
0
-10
-20
-30
-40
STRESS, KSI
0
60
120
180
240
300
360
420
480
540
600
MERIDIONAL DISTANCE, S.IN
AVERAGE STRESS
O =MERIDIAN
□ =HOOP

FIG 15


80
60
40
20
0
-20
-40
-60
-80
STRESS, KSI
0
60
120
180
240
300
360
420
480
540
600
MERIDIONAL DISTANCE, S.IN
OUTSIDE SURFACE
=MERIDIAN
=HOOP

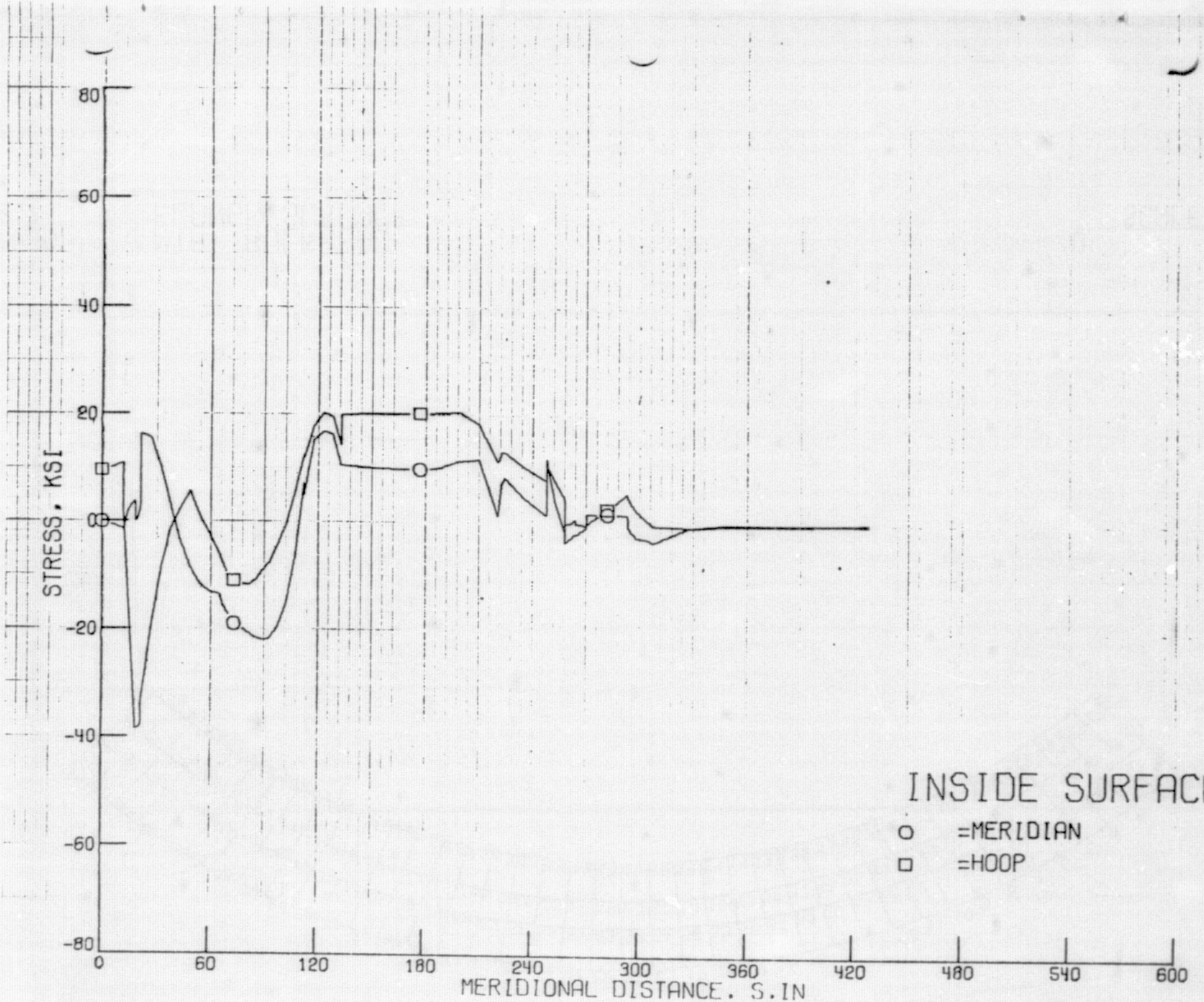
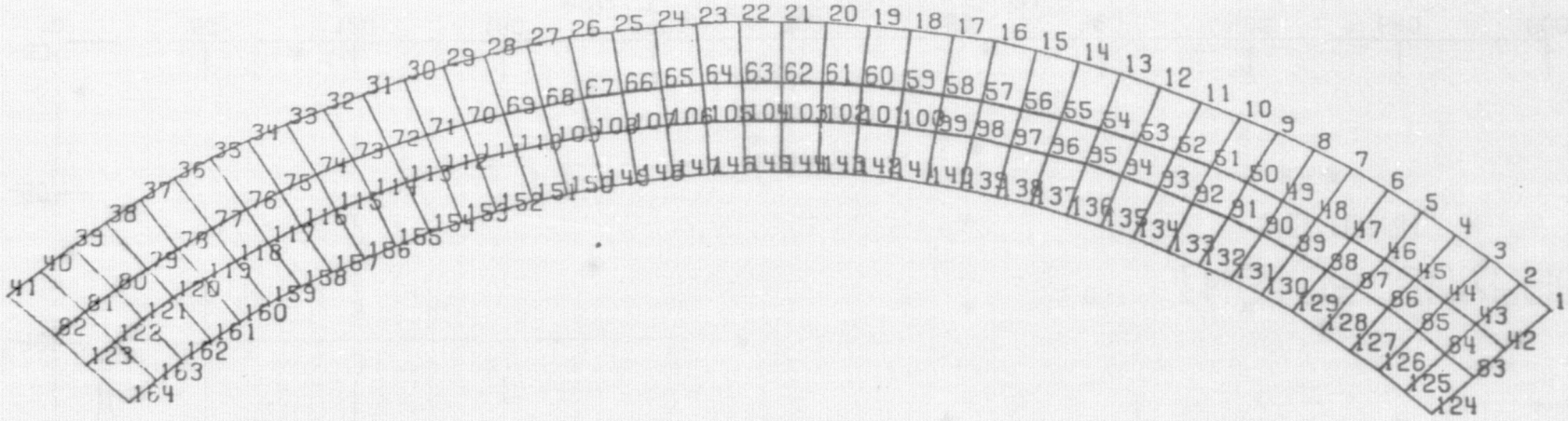

80
60
40
20
0
-20
-40
-60
-80
STRESS, KSI
0
60
120
180
240
300
360
420
480
540
600
MERIDIONAL DISTANCE. S.IN
INSIDE SURFACE
=MERIDIAN
=HOOP

FIG 17

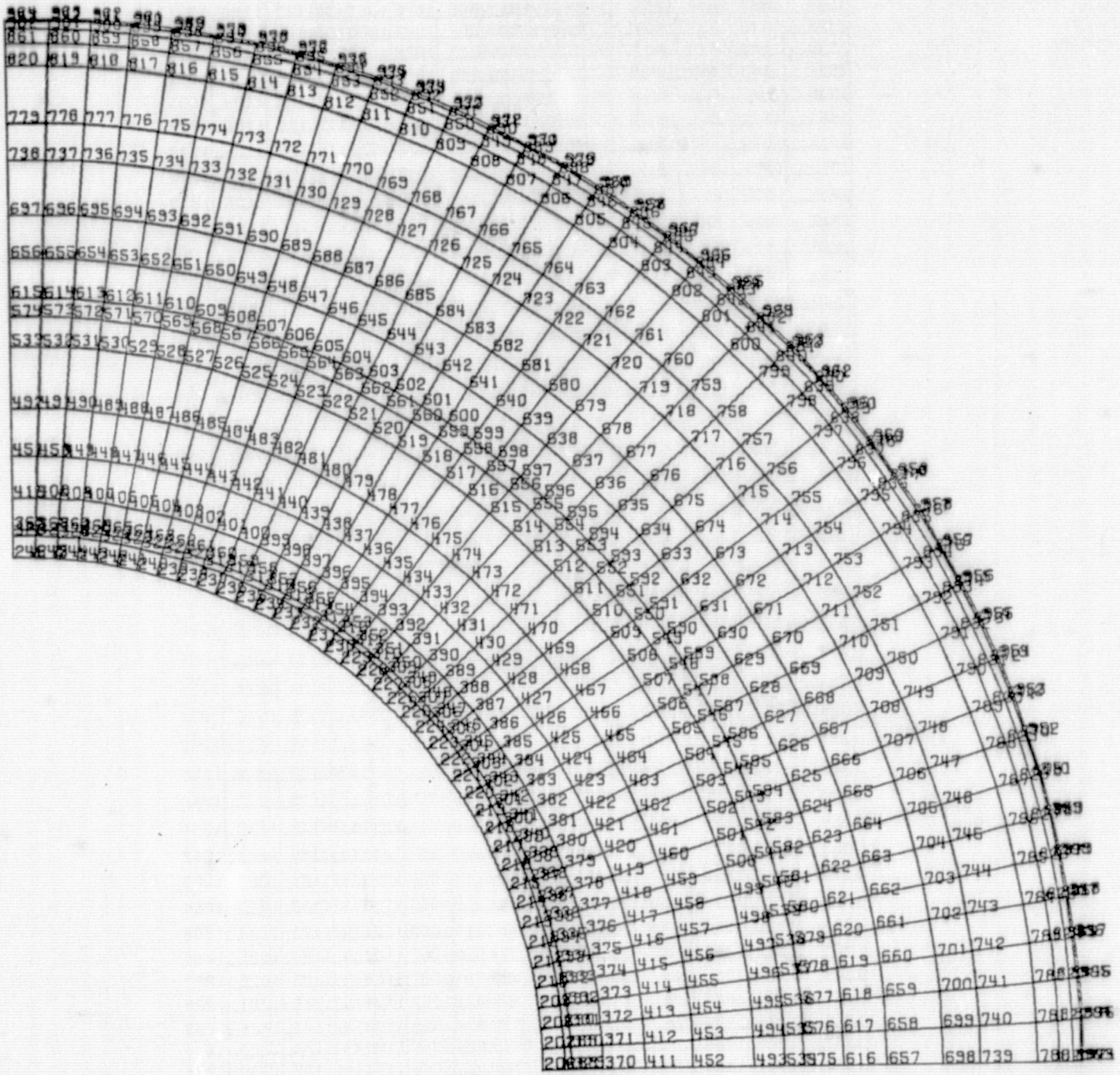


SPEC
2.1

NTF BULKHEAD
FLANGE SURFACE

0 21
SCALE

1-10

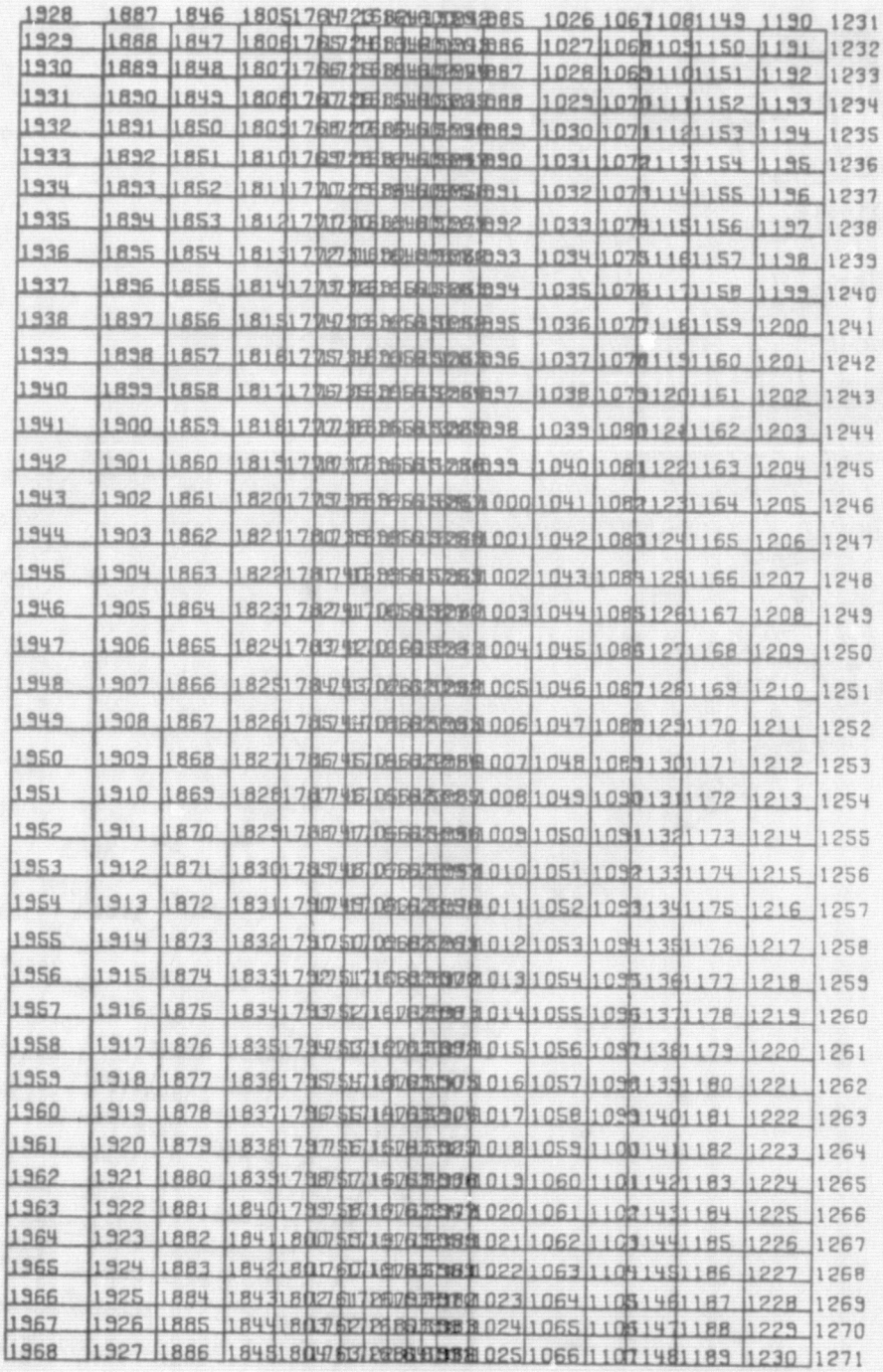


SPEC 3.1

NTF BULKHEAD DOME

0 26
SCALE

FIG. 19

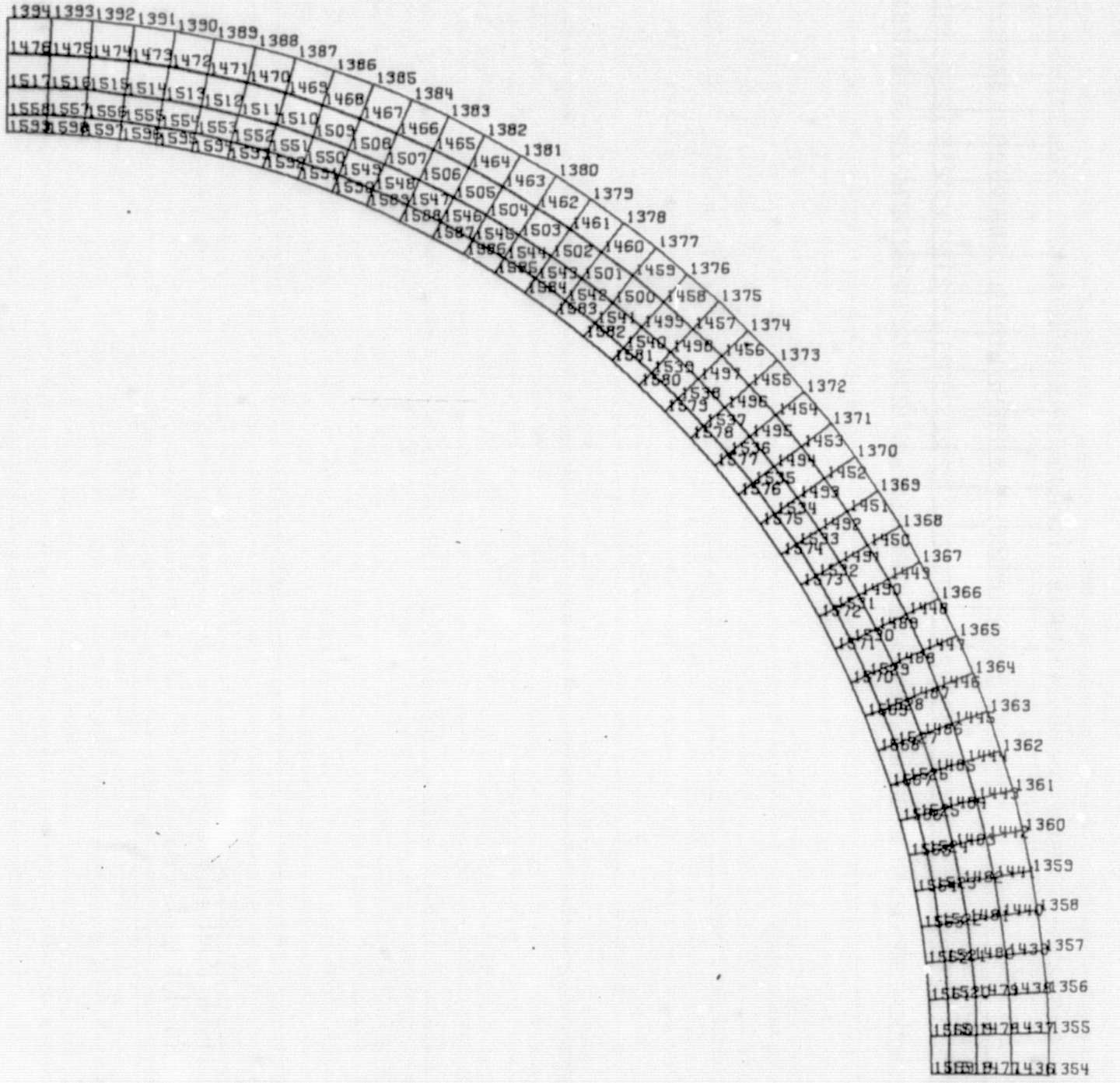


SPEC
.1

NTF BULKHEAD
SHELL

0 36
SCALE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

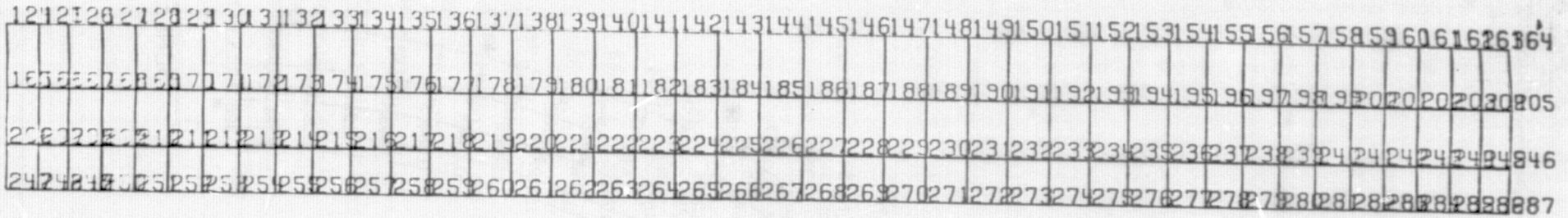


SPEC 9.1

NTF BULKHEAD
WEB OF TEE

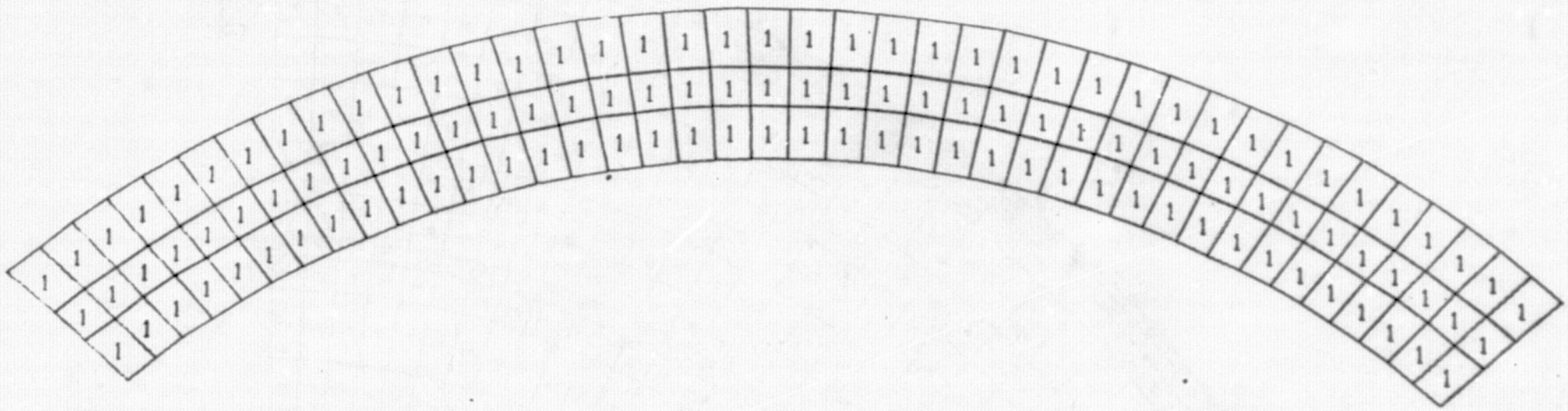
0 29
SCALE

FIG. 21



EC NTF BULKHEAD
.1 HATCH OPENING

0 1
SCALE



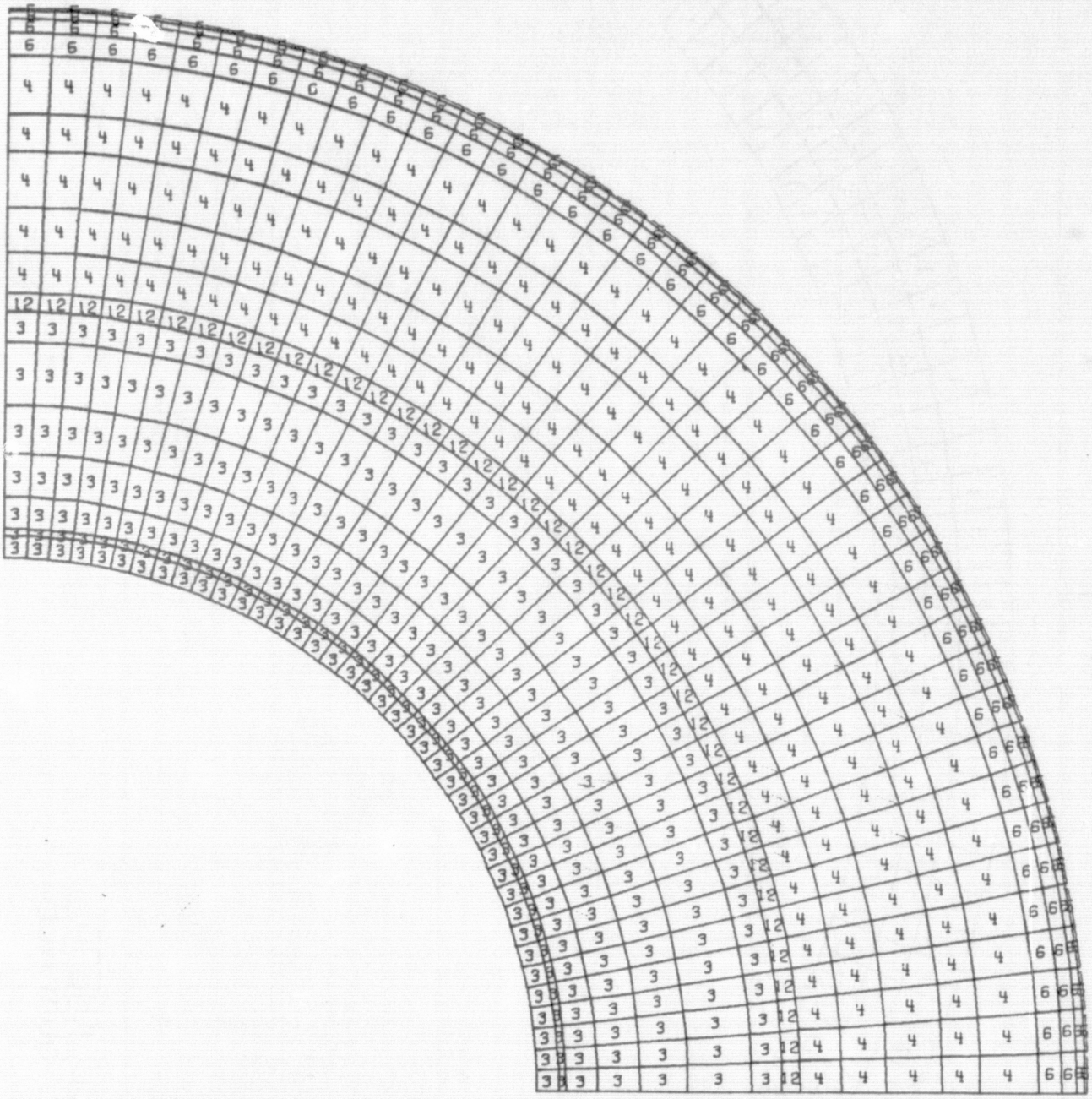
ELEMENT SECTION PROPERTY GROUPS

SPEC
2.1

NTF BULKHEAD
FLANGE SURFACE

0 21
SCALE

FIG. 23

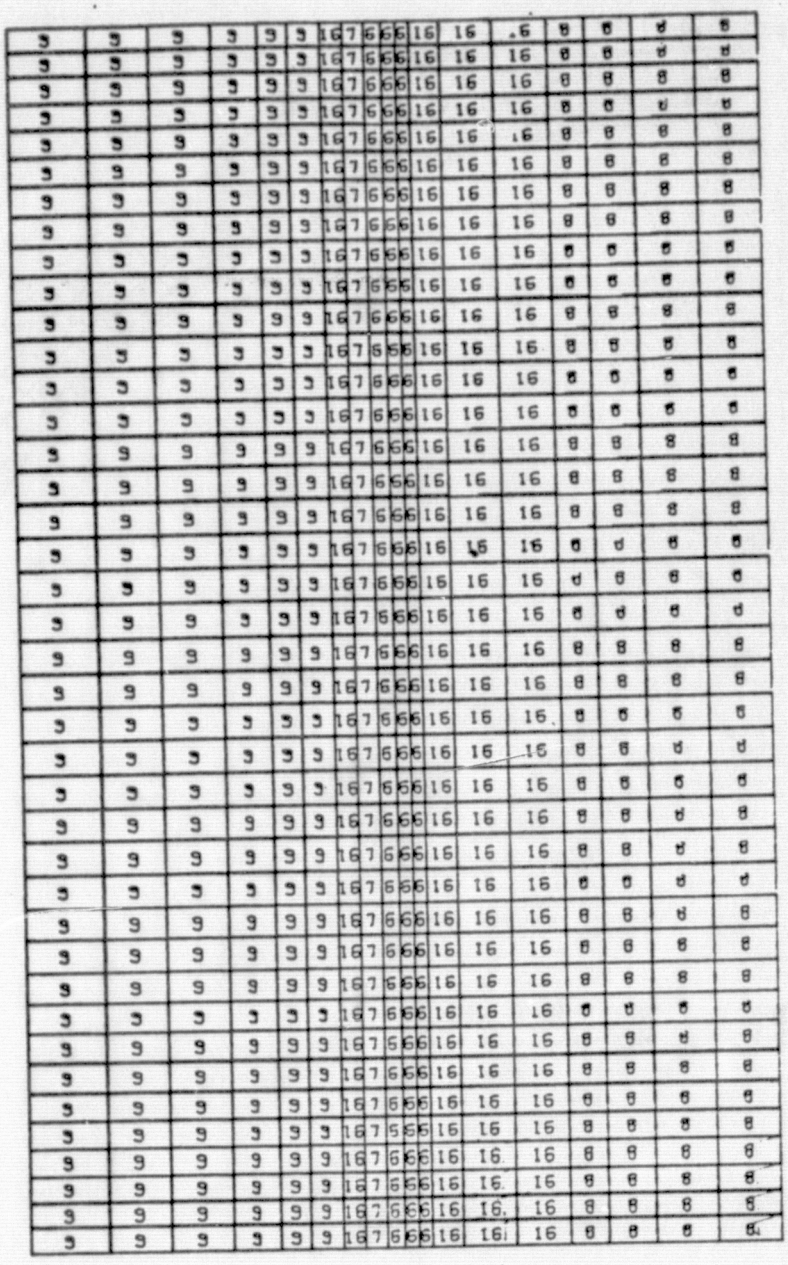


SPEC 3.1 NTF BULKHEAD DOME

0 2 SCALE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

FIG 3.1



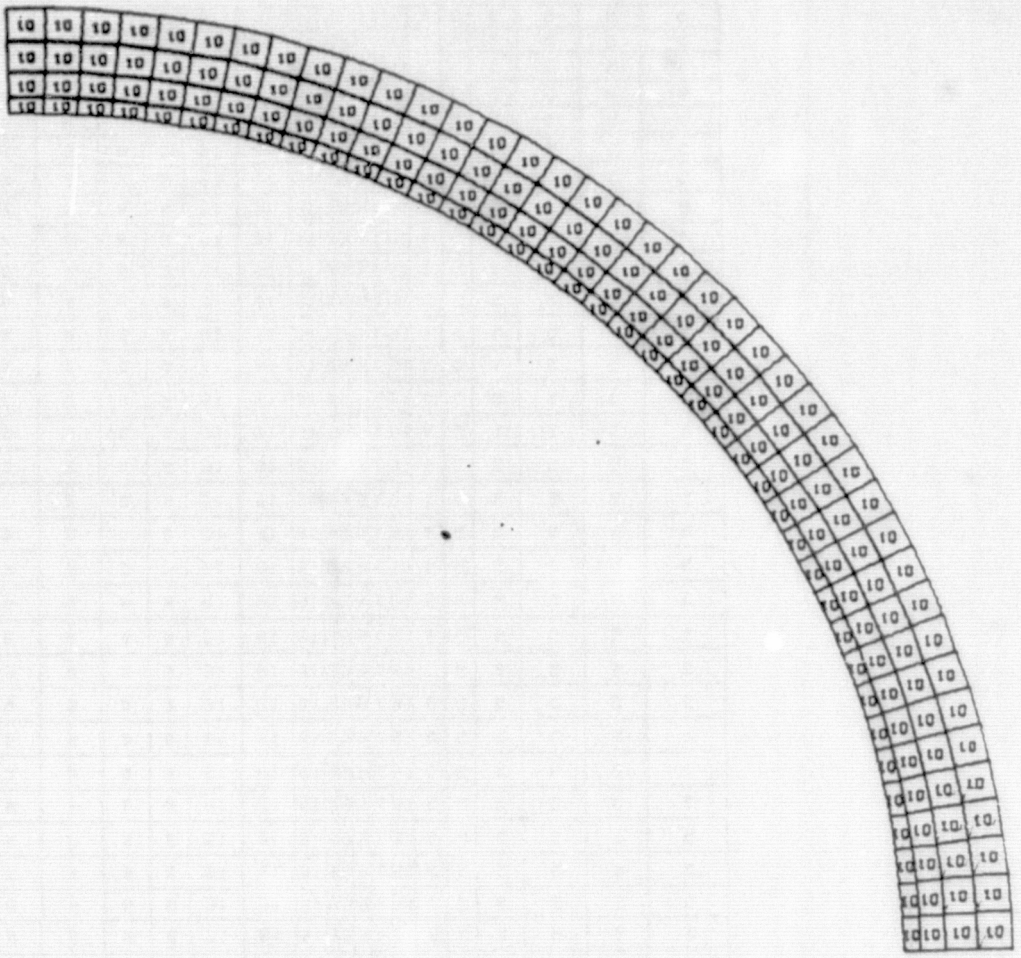
SPEC 5.1

NTF BULKHEAD SHELL

0 36
SCALE

ELEMENT SECTION PROPERTY GROUPS

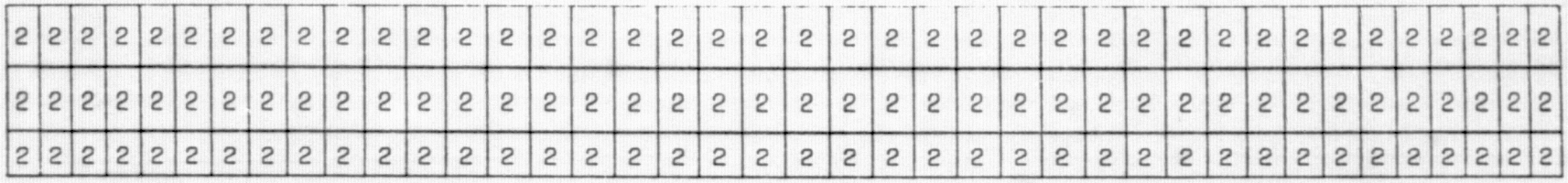
FIG. 25

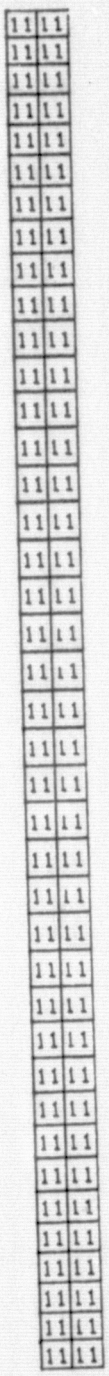


SPEC 9.1 NTF BULKHEAD WEB OF TEE

FIG. 21

ELEMENT SECTION PROPERTY GROUPS


2 2 2

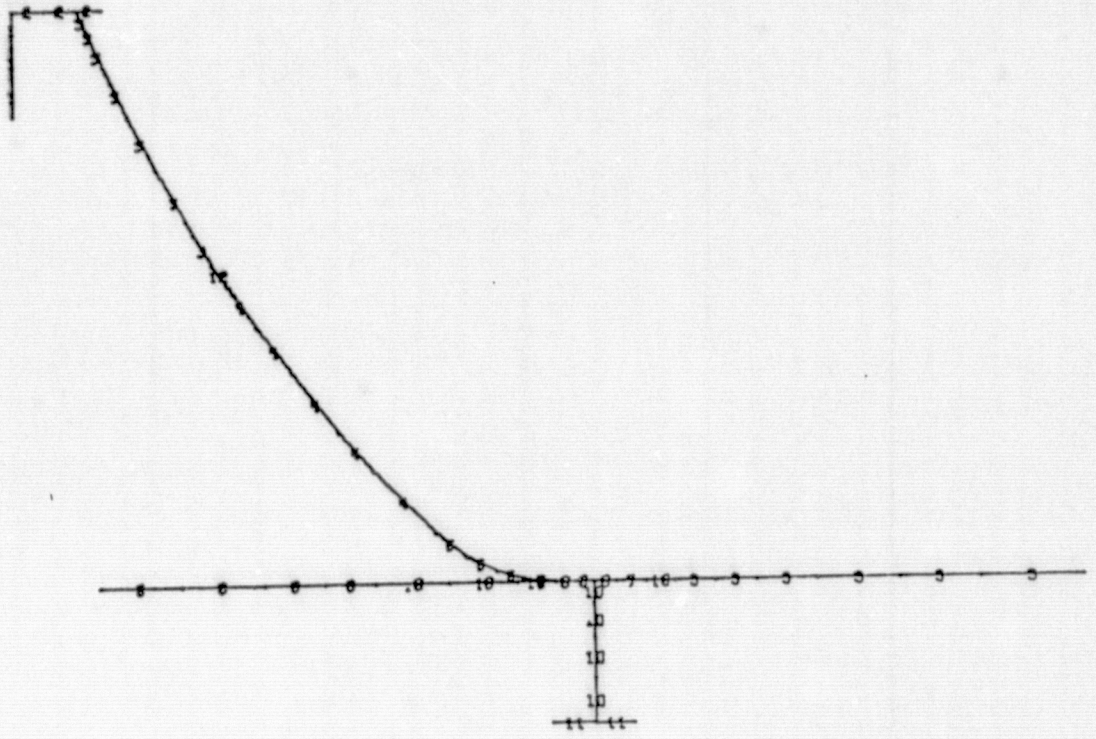


ELEMENT SECTION PROPERTY GROUPS

PEC
1.1

NTF BULKHEAD
TEE

0 SCALE 41



SPEC
12.1

NIF BULKHEAD
CROSS-SECTION VIEW

0 SCALE 24

ELEMENT SECTION PROPERTY GROUPS

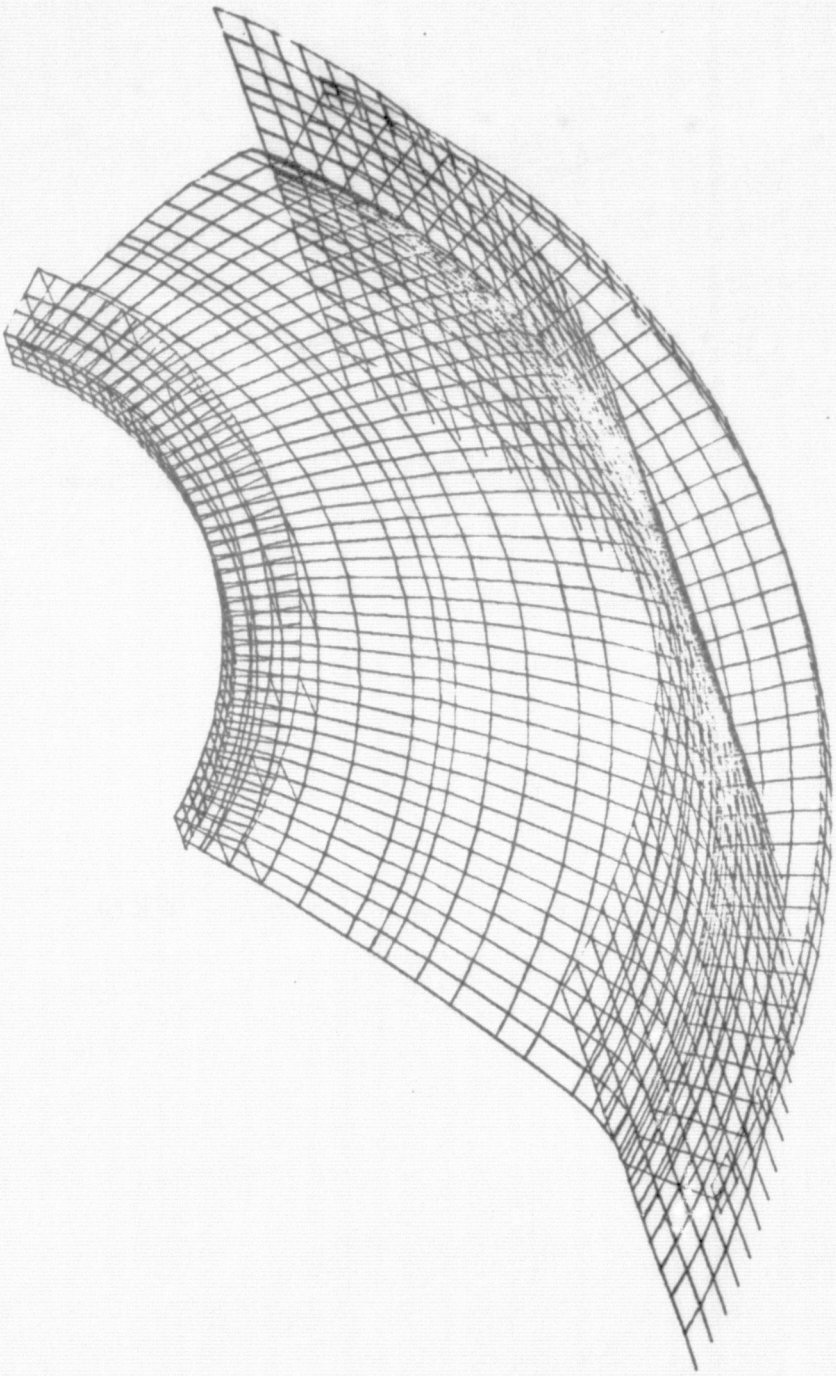
FIG. 29

Case 1

Valve Closed Stress plots

FIGURES 30 Thru 56

Computer run no. AKQ

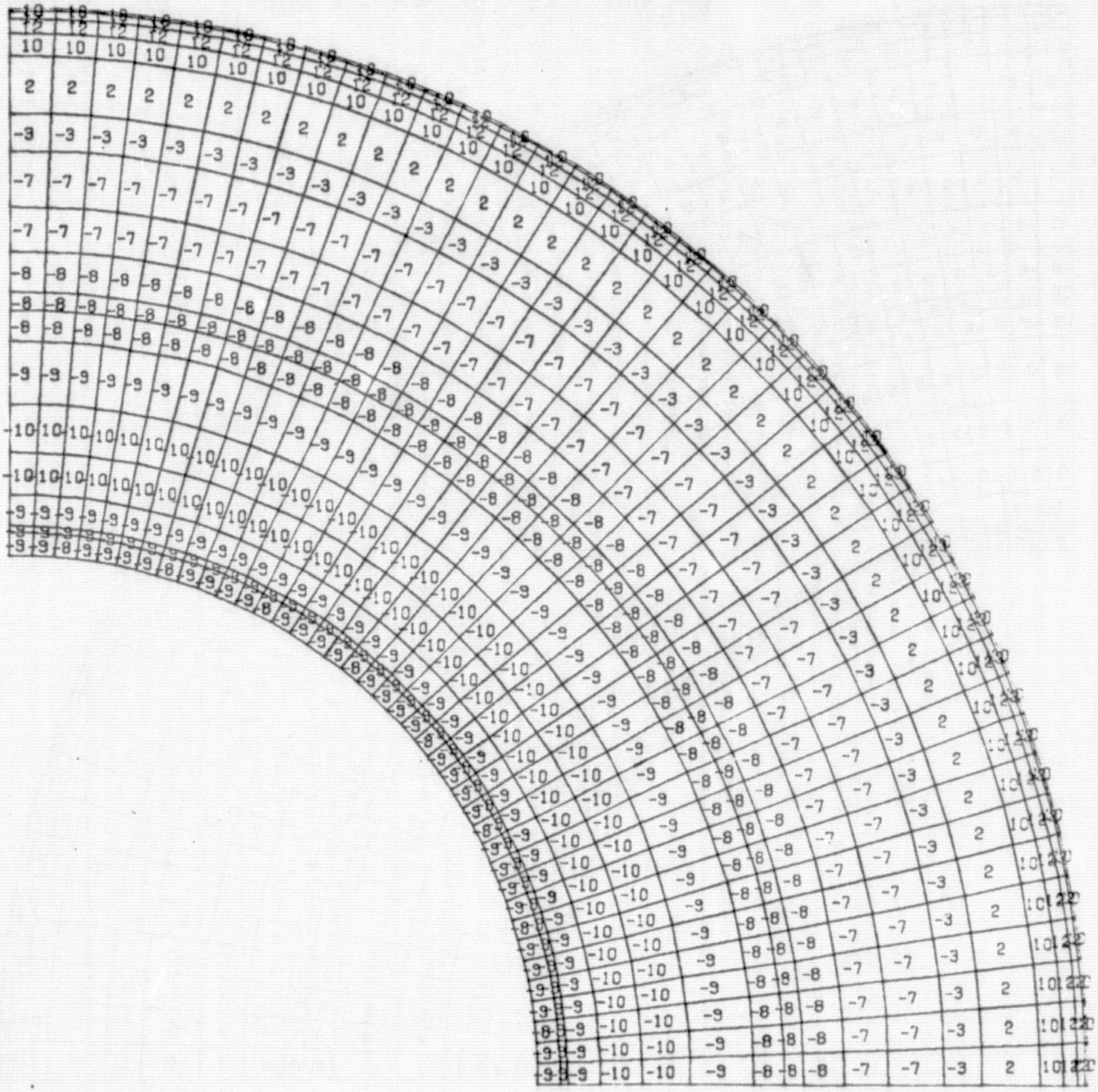


NTF BULKHEAD

0 41
SCALE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

DISPLAY= SX /1000 , NODE= 1, SURFACE= 0



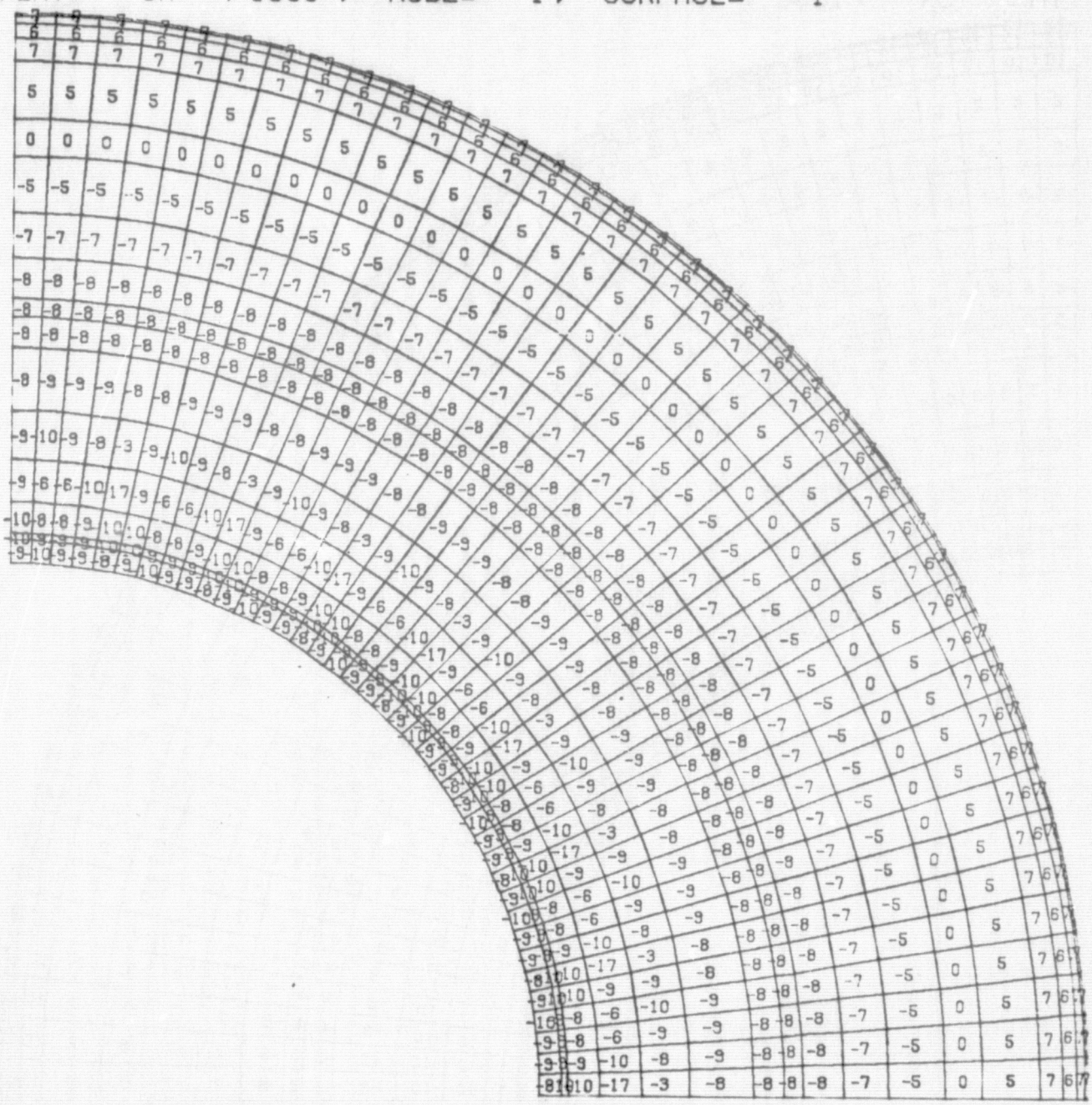
SPEC 3.1 NTF BULKHEAD DOME

0 SCALE 26

FIG. 31

DISPLAY= SX /1000 , NODE= 1, SURFACE= 1

1/1/1



SPEC 3.1

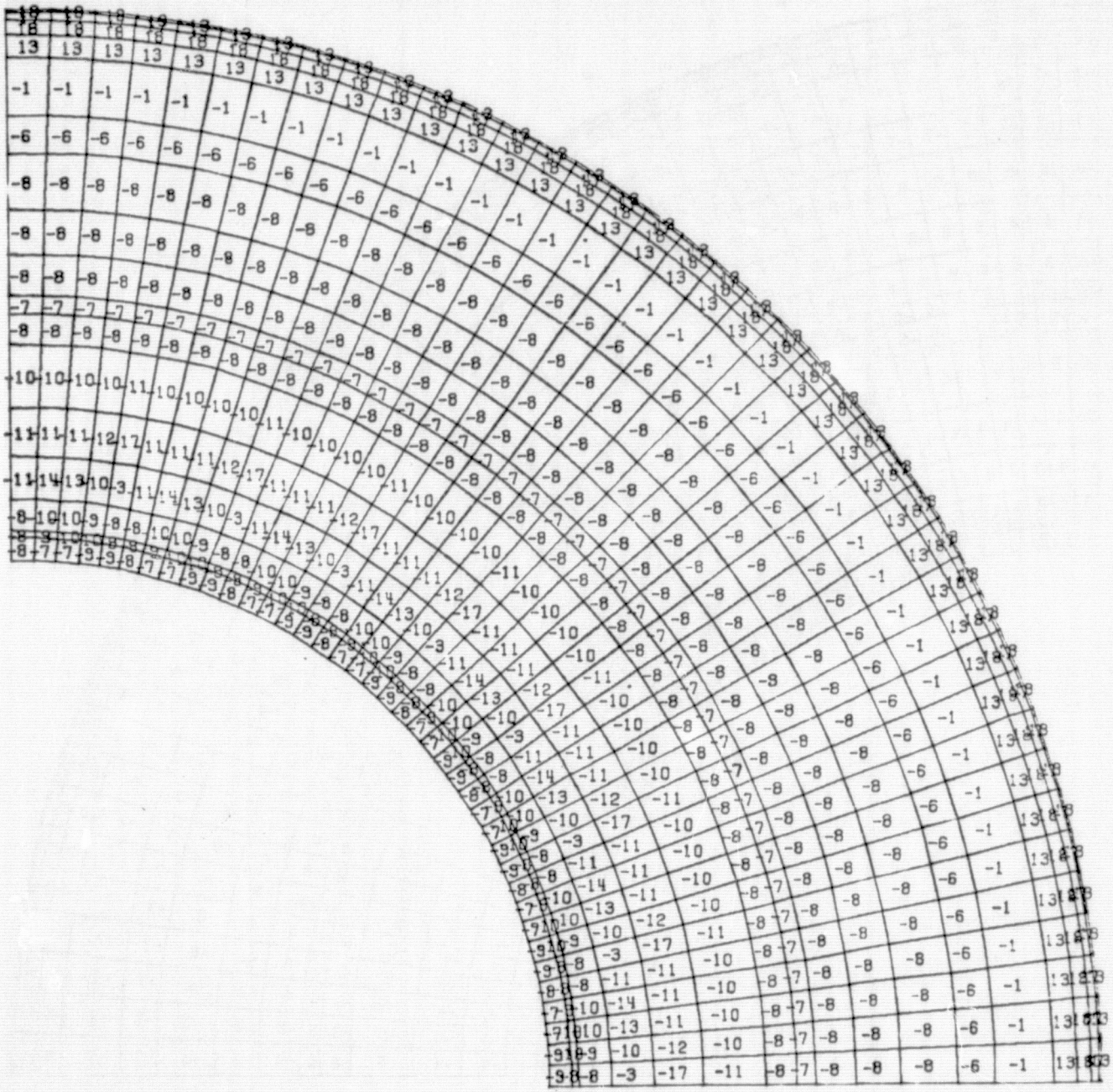
NTF BULKHEAD DOME

0 SCALE 26

FIG 27

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2



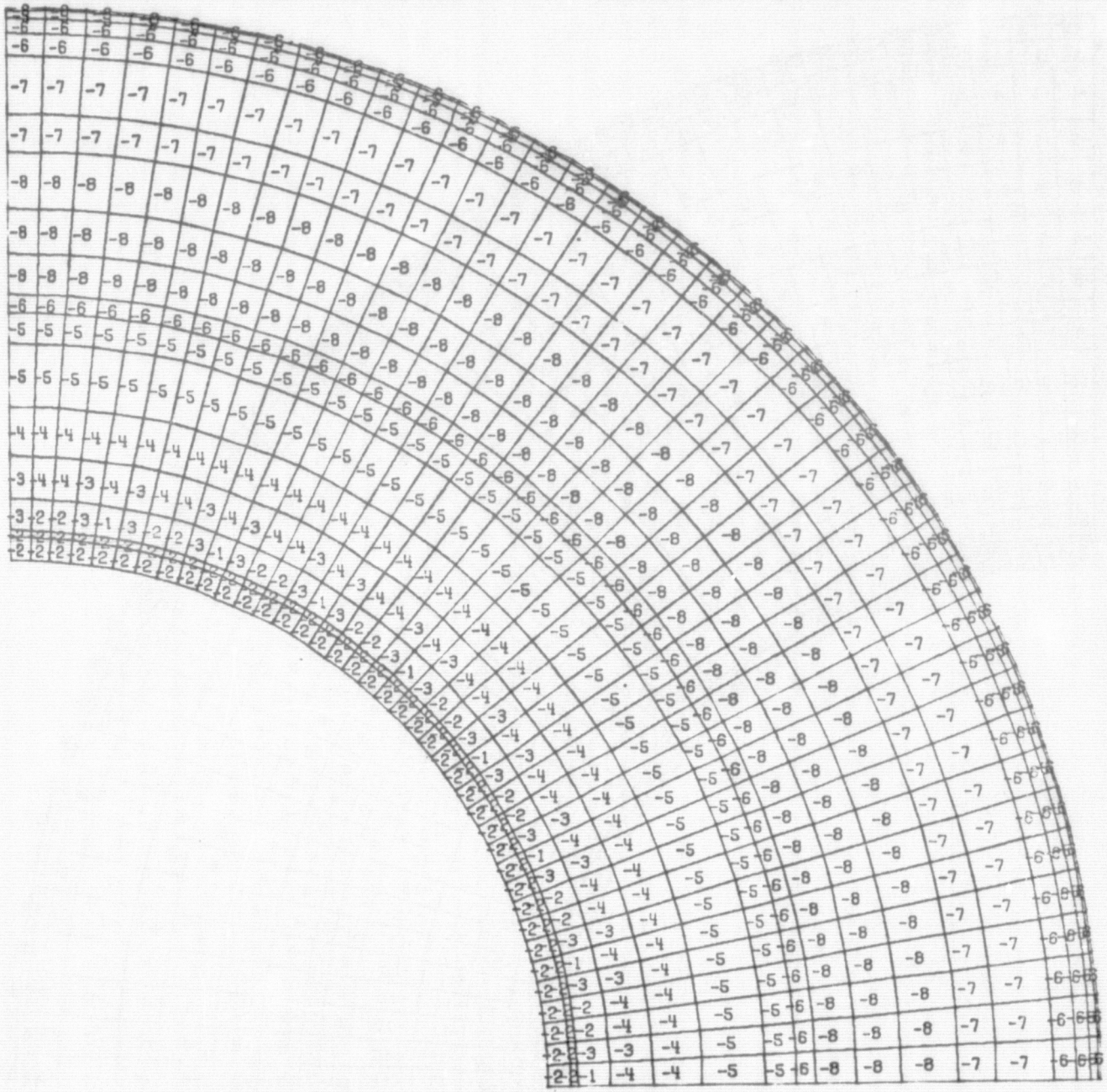
SPEC 3.1 NTF BULKHEAD DOME

0 26
SCALE

FIG. 33

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0



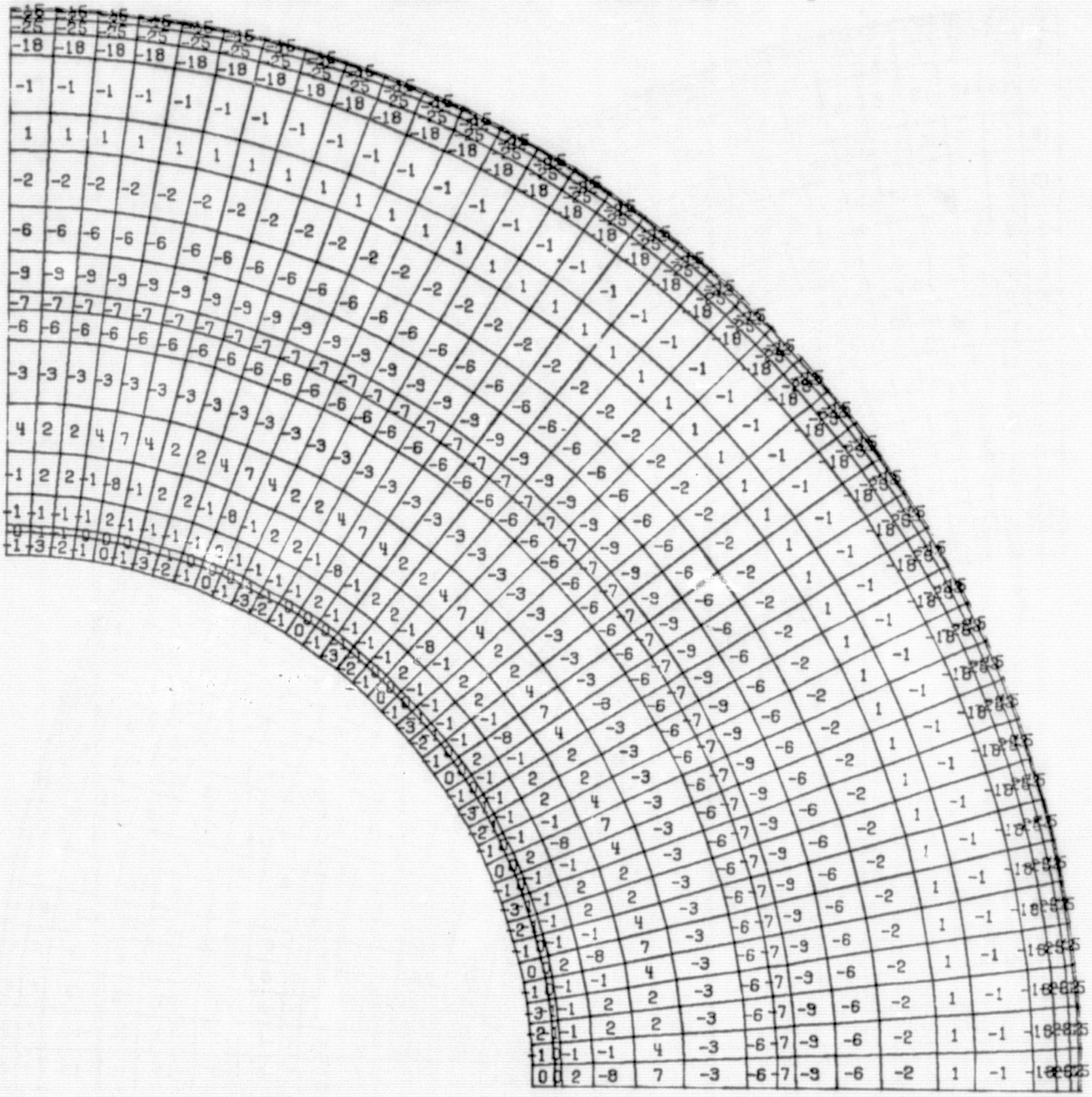
SPEC 3.1 NTF BULKHEAD DOME

0 SCALE 26

FIG 34

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1

1/1/1



SPEC 3.1

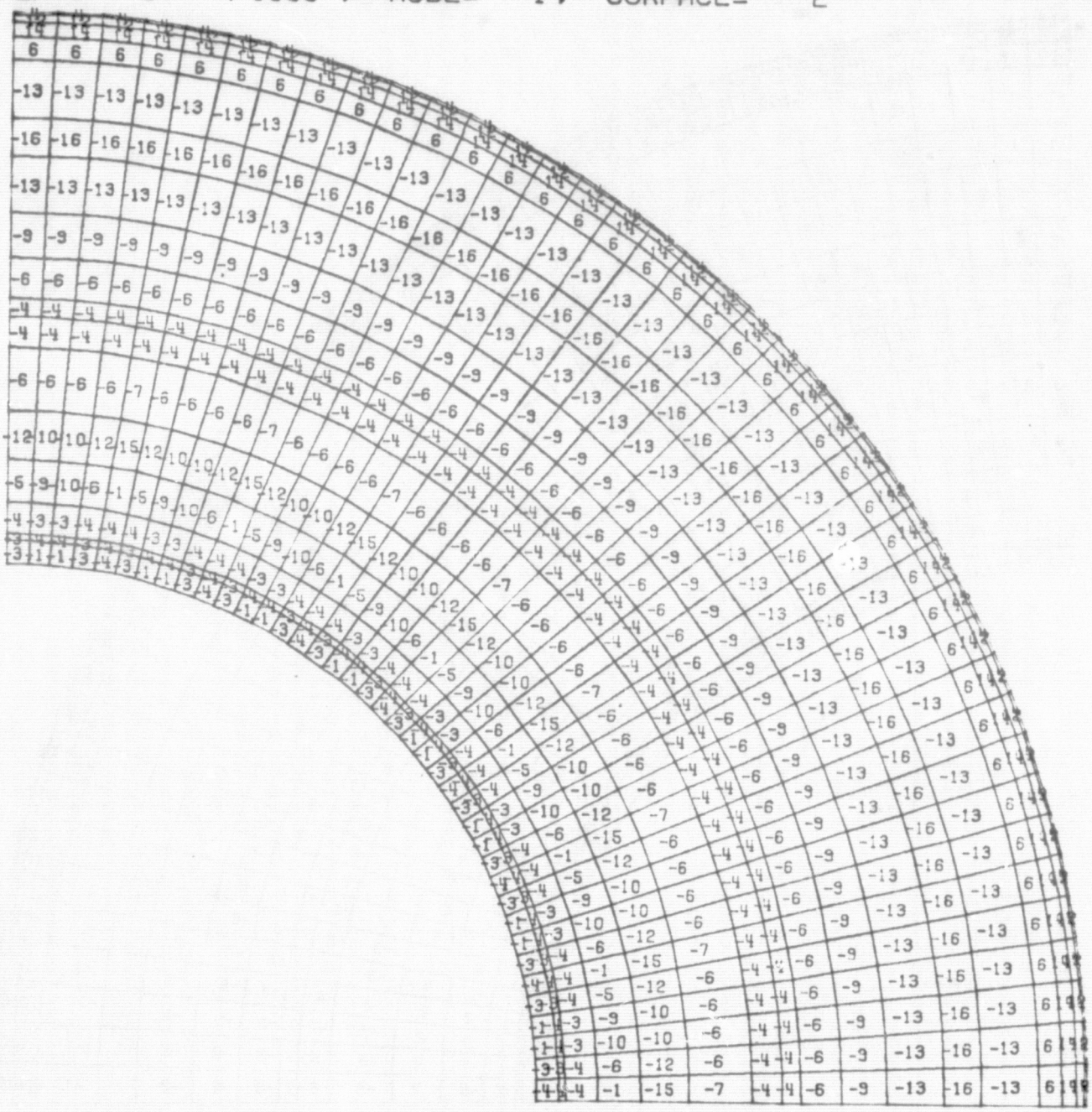
NTF BULKHEAD DOME

0 SCALE 26

FIG. 35

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2

1/1/1



SPEC 3.1 NTF BULKHEAD DOME

0 26
SCALE

Fig. 21

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0

0	0	-1	-1	-1	0	2	3	5	7	9	10	13	14	16	18	20	20

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1

1/1/1

0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20
0	0	-1	0	0	2	3	5	7	7	6	14	15	14	15	18	20	20

SPEC 5.1 NIF BULKHEAD SHELL

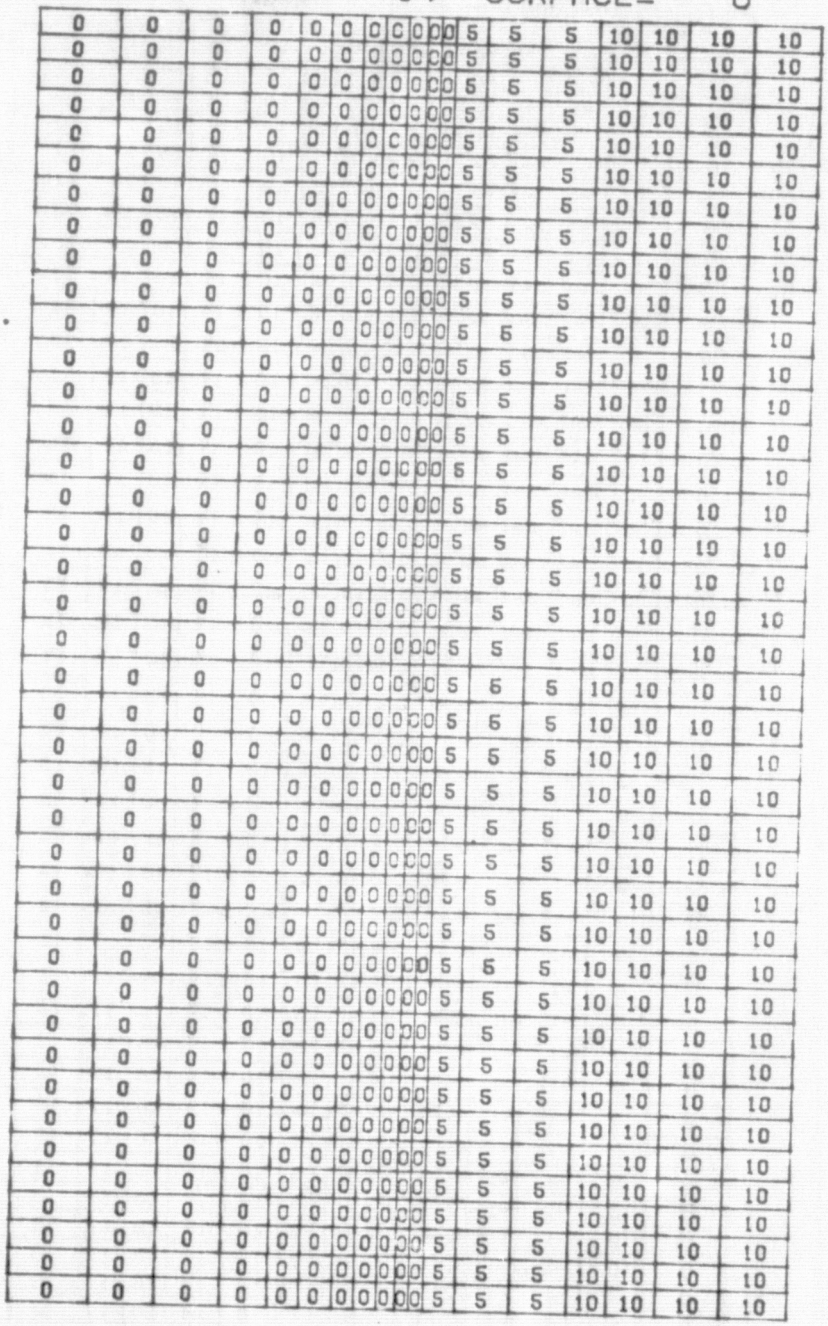
0 36
SCALE

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2

0	0	-1	-1	-2	-1	0	2	4	7	11	16	10	14	18	17	19	20

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 0 1/1/1



SPEC 5.1 NIF BULKHEAD SHELL

0 36
SCALE

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1

0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10
0	-1	0	1	3	5	5	6	5	8	19	12	5	5	11	12	10

SPEC 5.1 NIF BULKHEAD SHELL

0 SCALE 36

FIG, 41

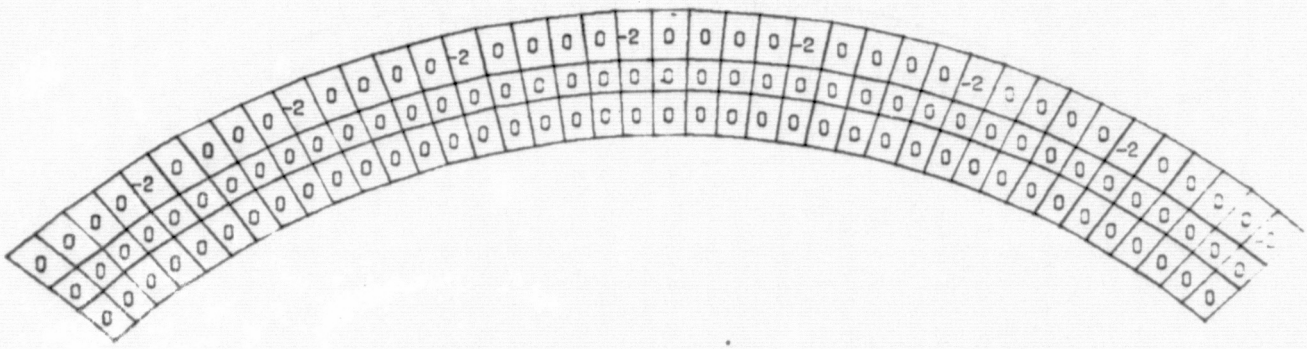
DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2 1/1/1

0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10
0	0	0	-2	-4	-6	-5	-6	-6	-7	-9	-2	5	15	9	8	10

SPEC 5.1 NIF BULKHEAD SHELL

0 36
SCALE

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0



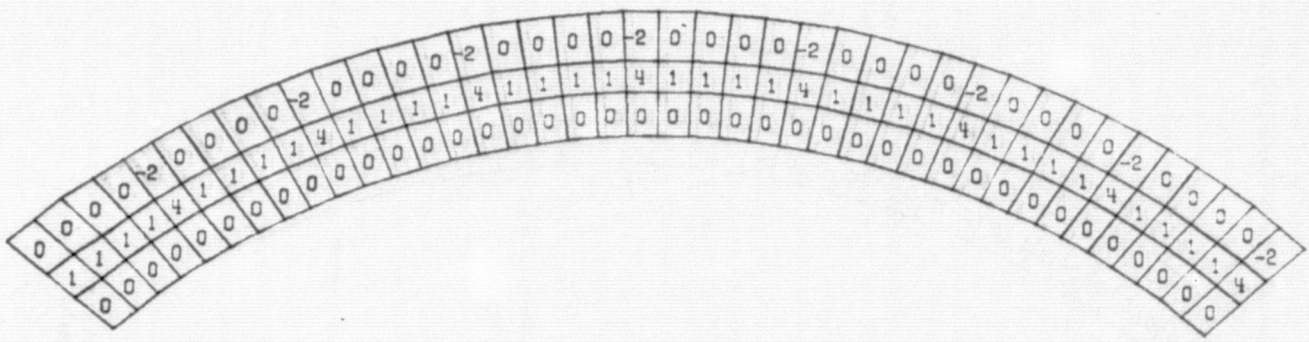
SPEC 2.1 NTF BULKHEAD FLANGE SURFACE

0 SCALE 21

FIG. 43

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1

1/1/1



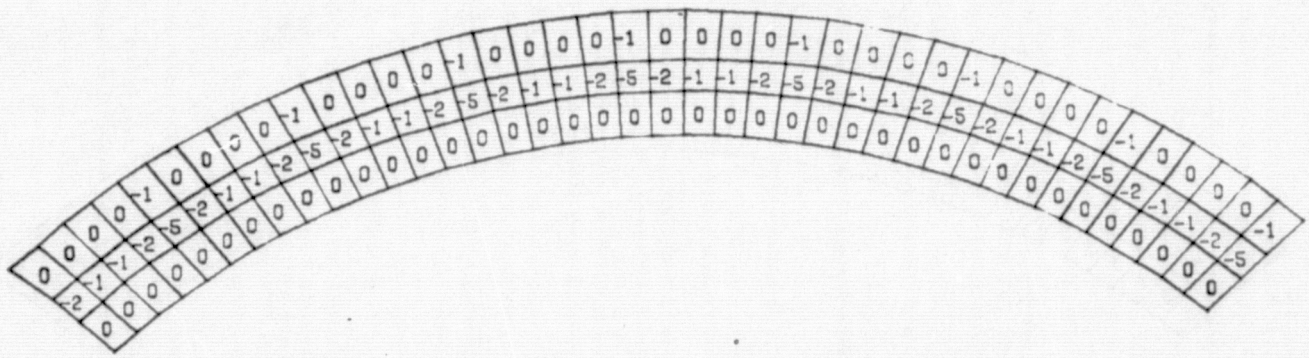
SPEC 2.1 NTF BULKHEAD FLANGE SURFACE

0 21
SCALE

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2



0 21
SCALE

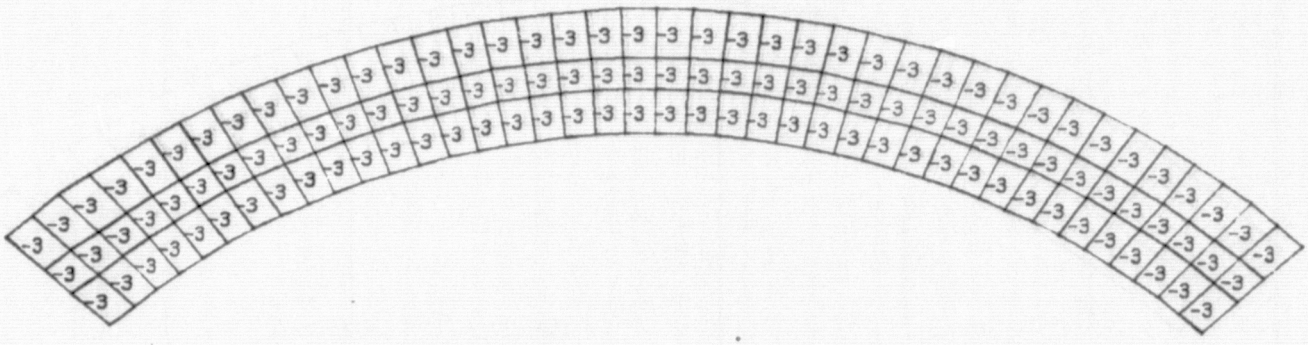
SPEC
2.1

NTF BULKHEAD
FLANGE SURFACE

FIG. 45

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0

1/1/1



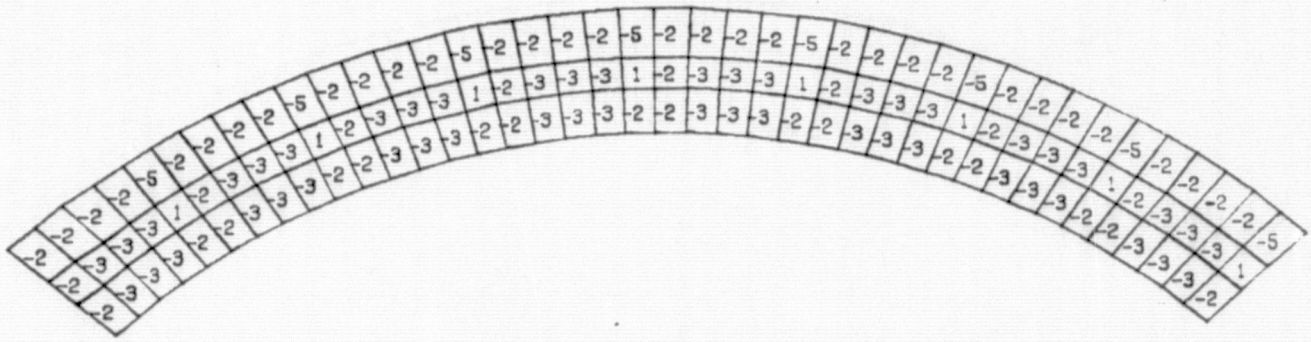
SPEC 2.1

NTF BULKHEAD FLANGE SURFACE

0 21
SCALE

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1

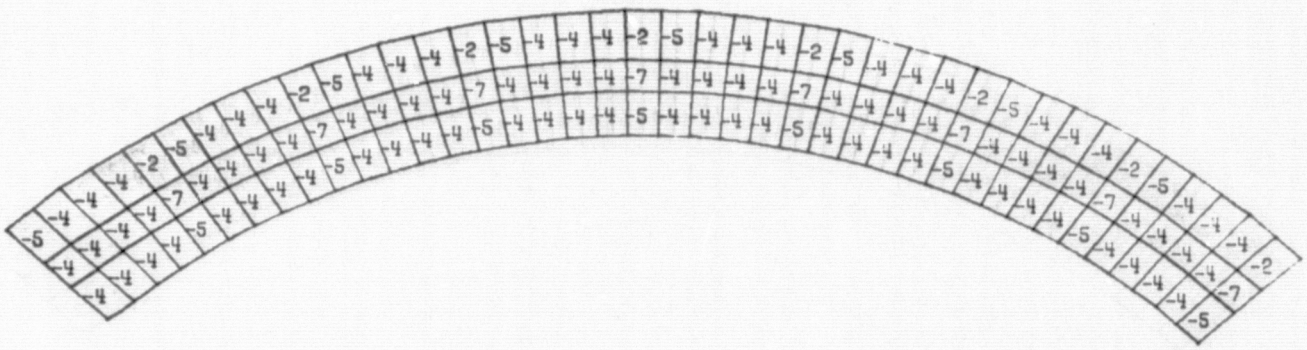


SPEC 2.1 NTF BULKHEAD FLANGE SURFACE

0 21 SCALE

FIG. 47

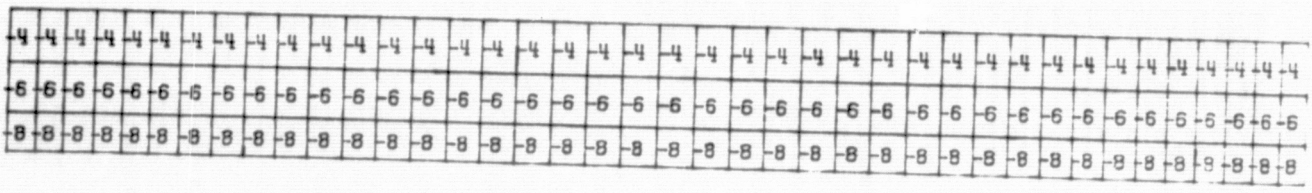
DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2 1/1/1



SPEC 2.1 NTF BULKHEAD FLANGE SURFACE

0 SCALE 21

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0 1/1/1



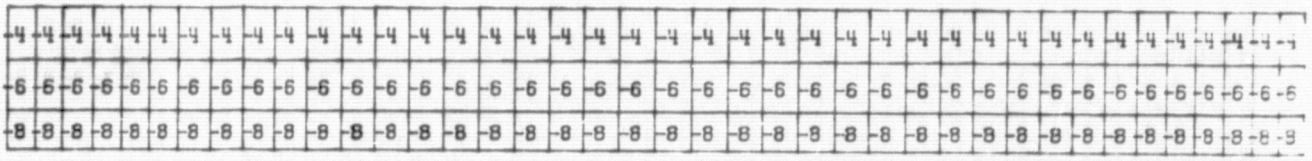
SPEC 10.1 NTF BULKHEAD HATCH OPENING

0 18
SCALE

FIG. 49

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1

1/1/1



SPEC 10.1

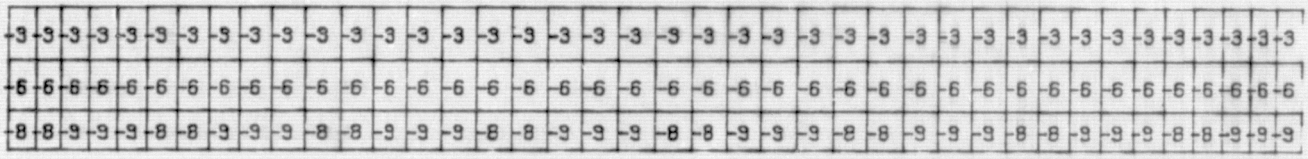
NTF BULKHEAD
HATCH OPENING

0 18
SCALE

FIG. 50

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2

1/1/1



SPEC 10.1

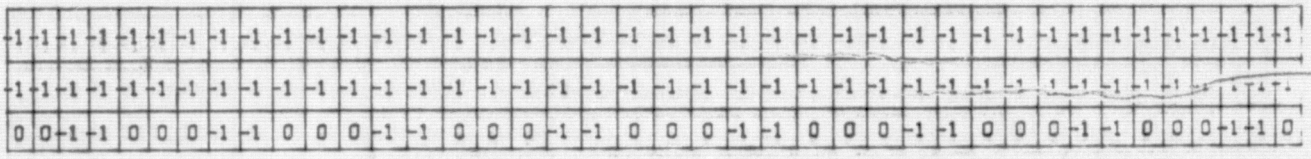
NTF BULKHEAD HATCH OPENING

0 SCALE 18

FIG. 51

1/1/1

)DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0



SPEC 10.1
NTF BULKHEAD HATCH OPENING

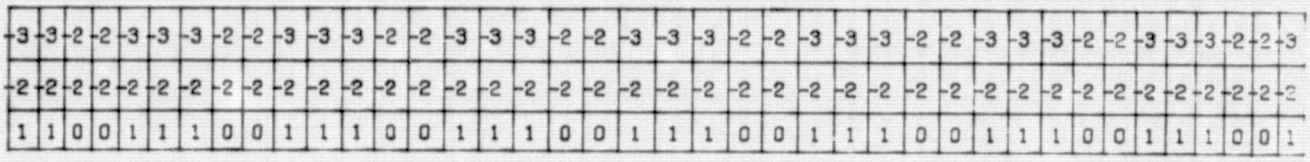
0 18
SCALE

)

FIG. 52

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1

1/1/1



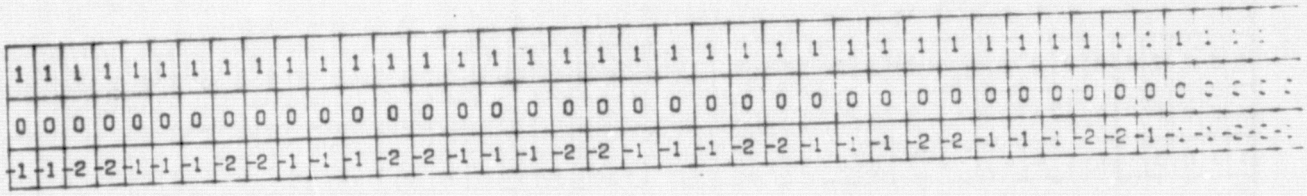
SPEC 10.1

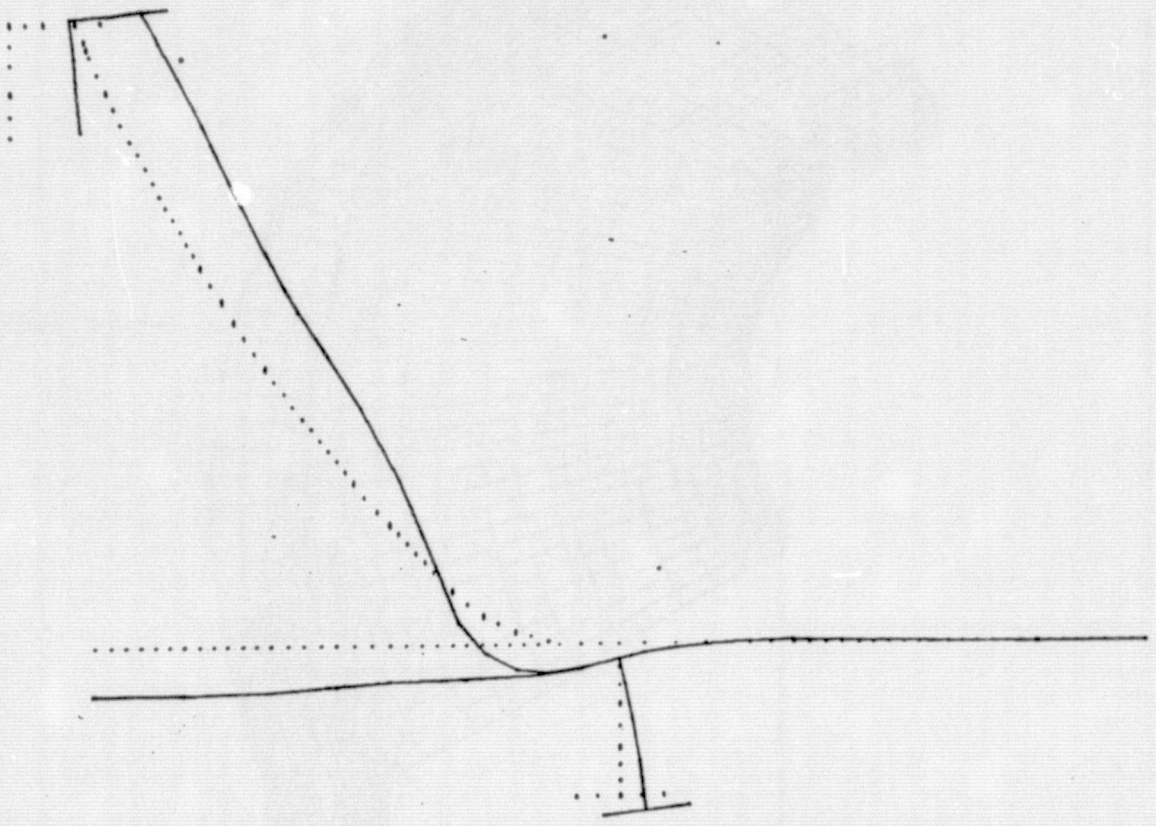
NTF BULKHEAD HATCH OPENING

0 SCALE 18

FIG. 53

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2


1 1 1



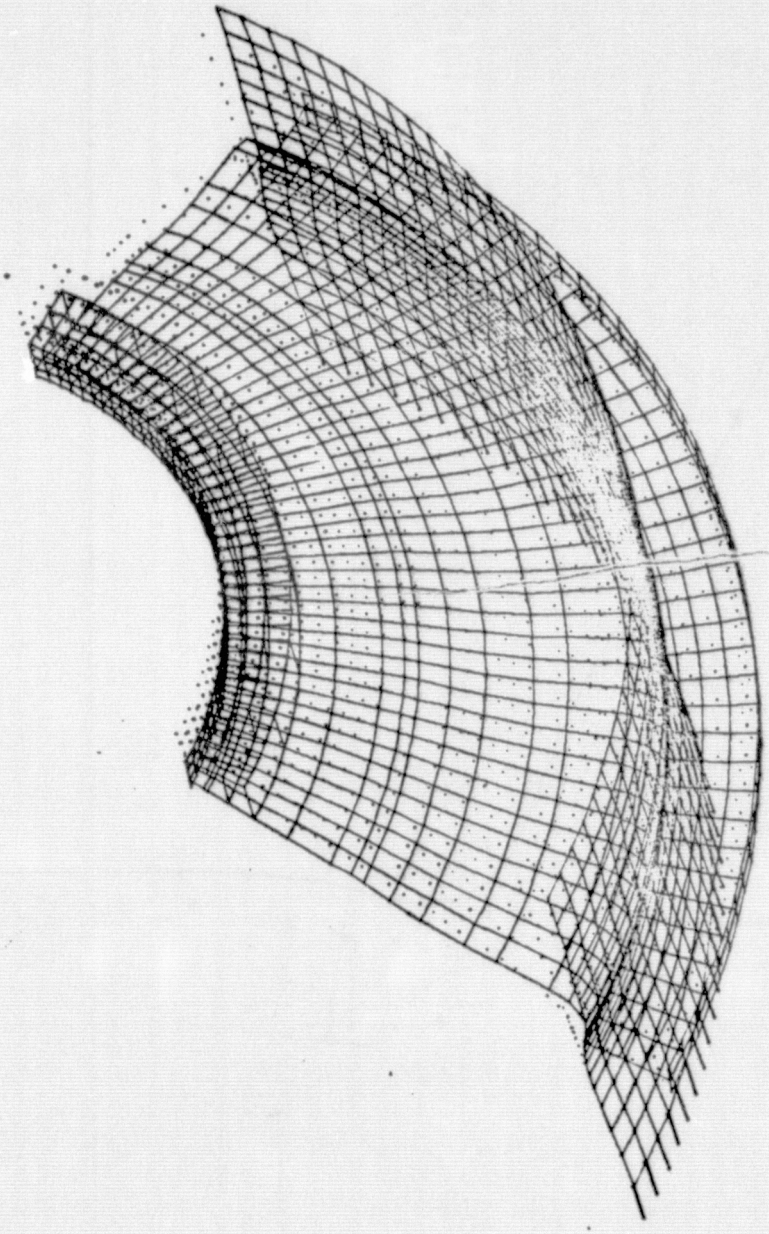
SPEC
12.1

NTF BULKHEAD
CROSS-SECTION VIEW

0 SCALE 27

FIG. 55

1/1/1



SPEC
1.1

NTF BULKHEAD

0 44
SCALE

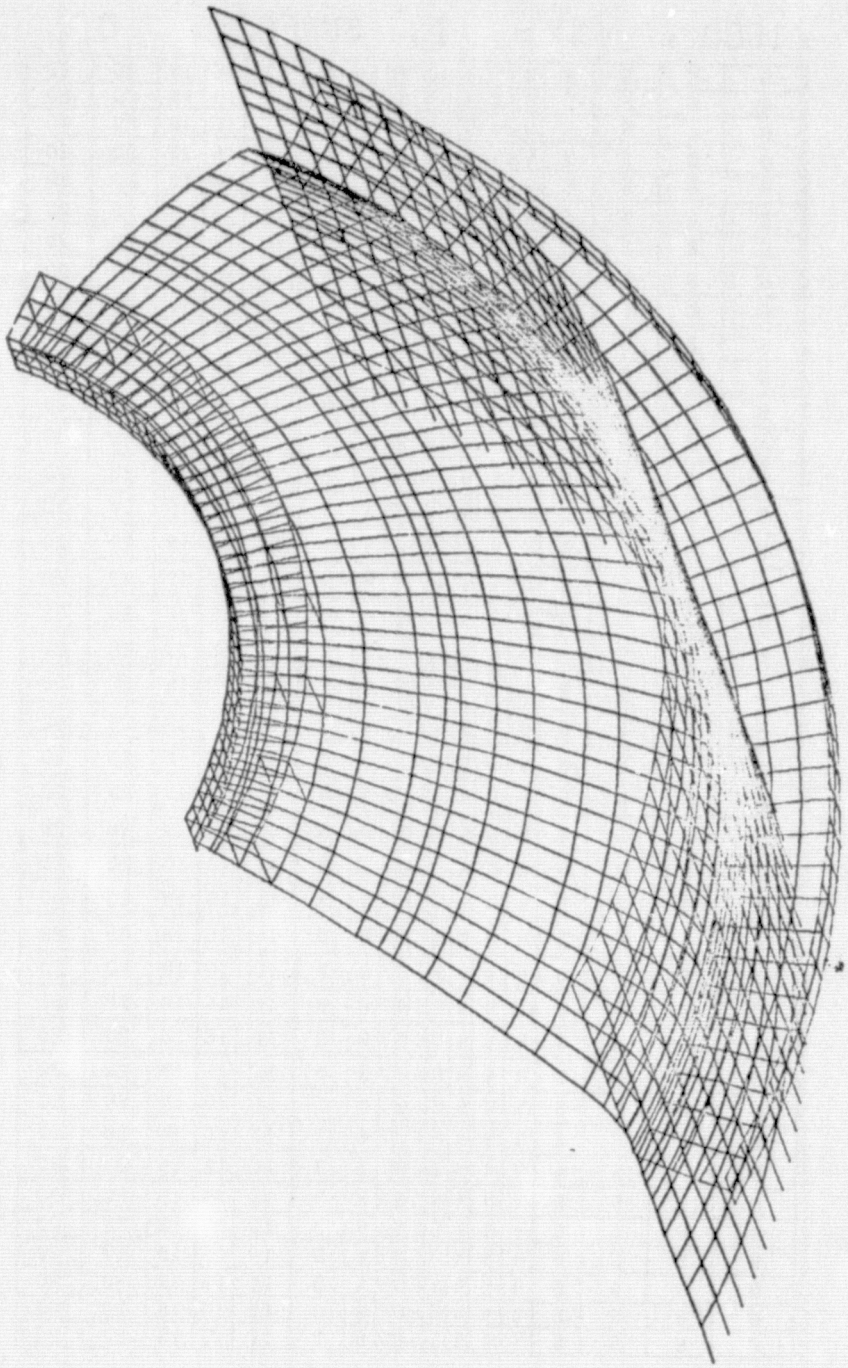
FIG. 56

Case 2

Valve open stress Plots

Figures 57 Thru 83

Computer run no. LGH



SPEC
1.1

NTF BULKHEAD

0 SCALE 11

FIG. 57

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0

6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20
6	6	5	5	4	4	4	5	5	6	7	8	9	11	15	18	20	20

SPEC 5.1 NTF BULKHEAD SHELL

0 36
SCALE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

FIG. 58

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1

6	5	5	5	5	5	5	6	7	8	10	11	14	18	20	20

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2

1/1/1

6	6	5	5	4	4	3	3	4	5	7	9	12	16	17	19	20

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0

2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10
2	2	2	2	2	2	2	2	2	2	5	5	5	10	10	10	10

SPEC 5.1 NTF BULKHEAD SHELL

0 SCALE 36

FIG 61

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1

2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10
2	2	2	2	3	5	5	6	8	10	8	6	4	7	12	12	10

SPEC 5.1 NTF BULKHEAD SHELL

0 SCALE 36

Fig 17

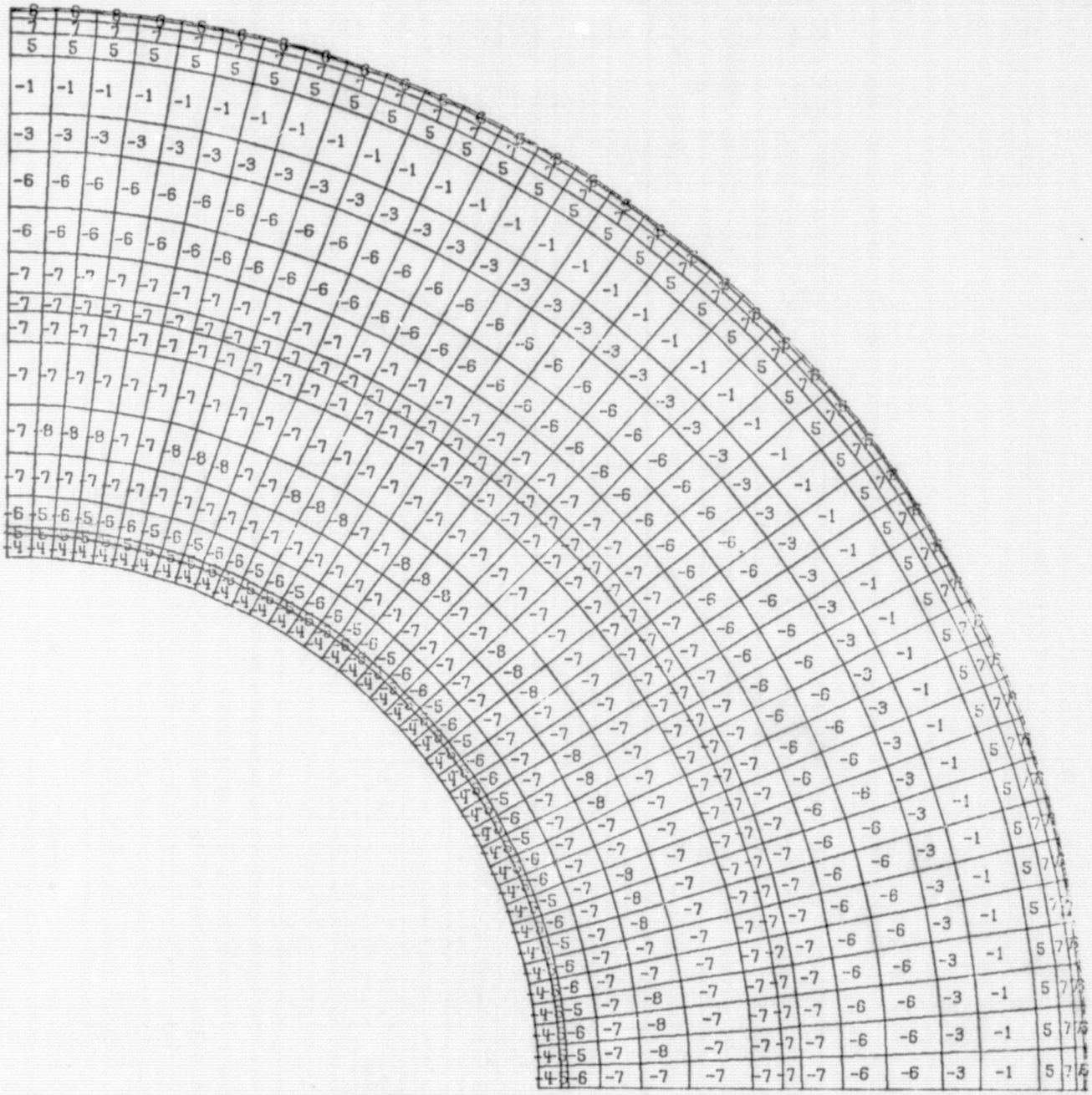
1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2

2	3	3	3	2	0	1	2	4	04	2	4	6	13	8	8	10

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0

1/1/1



SPEC 3.1

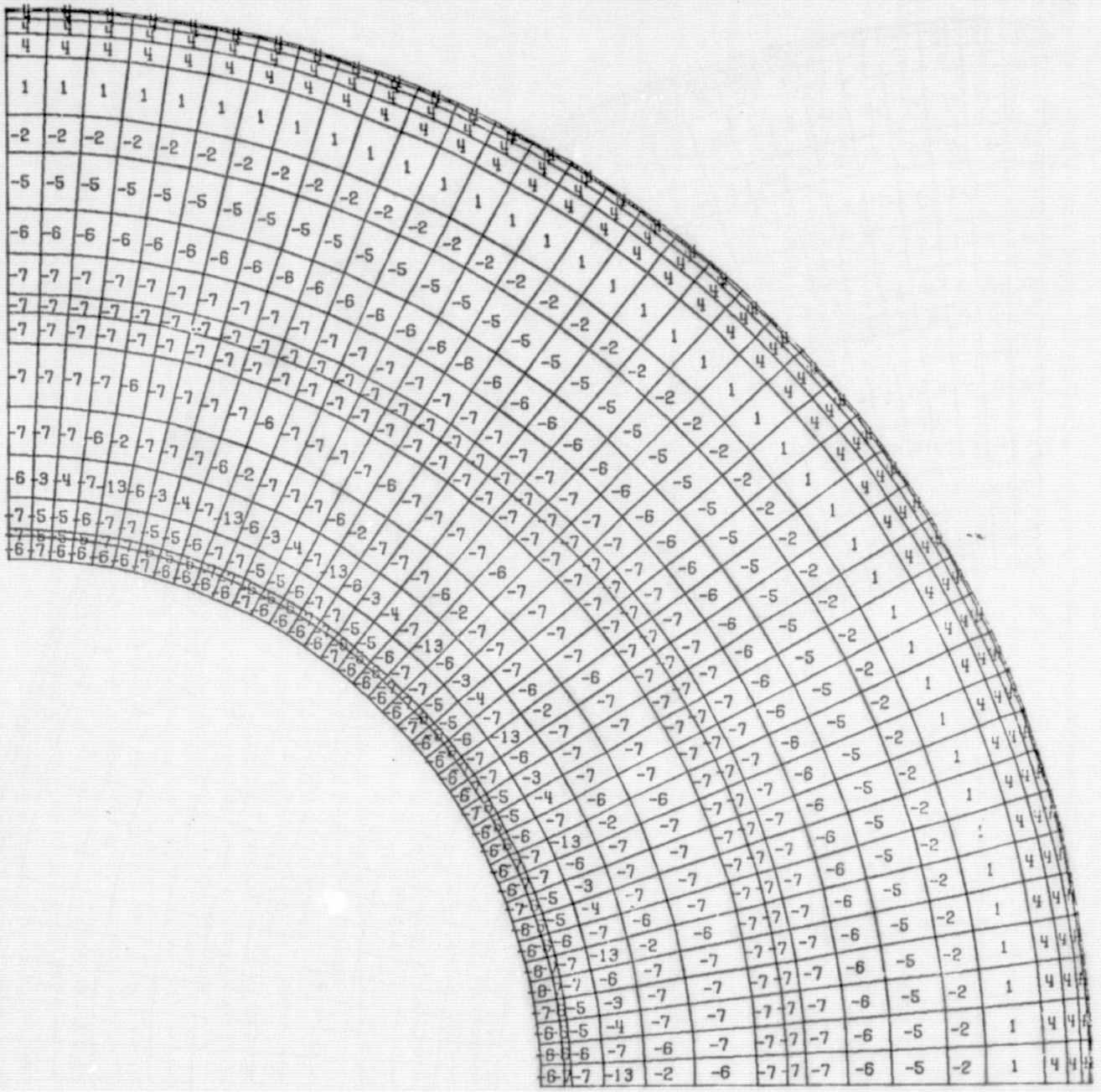
NTF BULKHEAD DOME

0 26
SCALE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1



SPEC 3.1

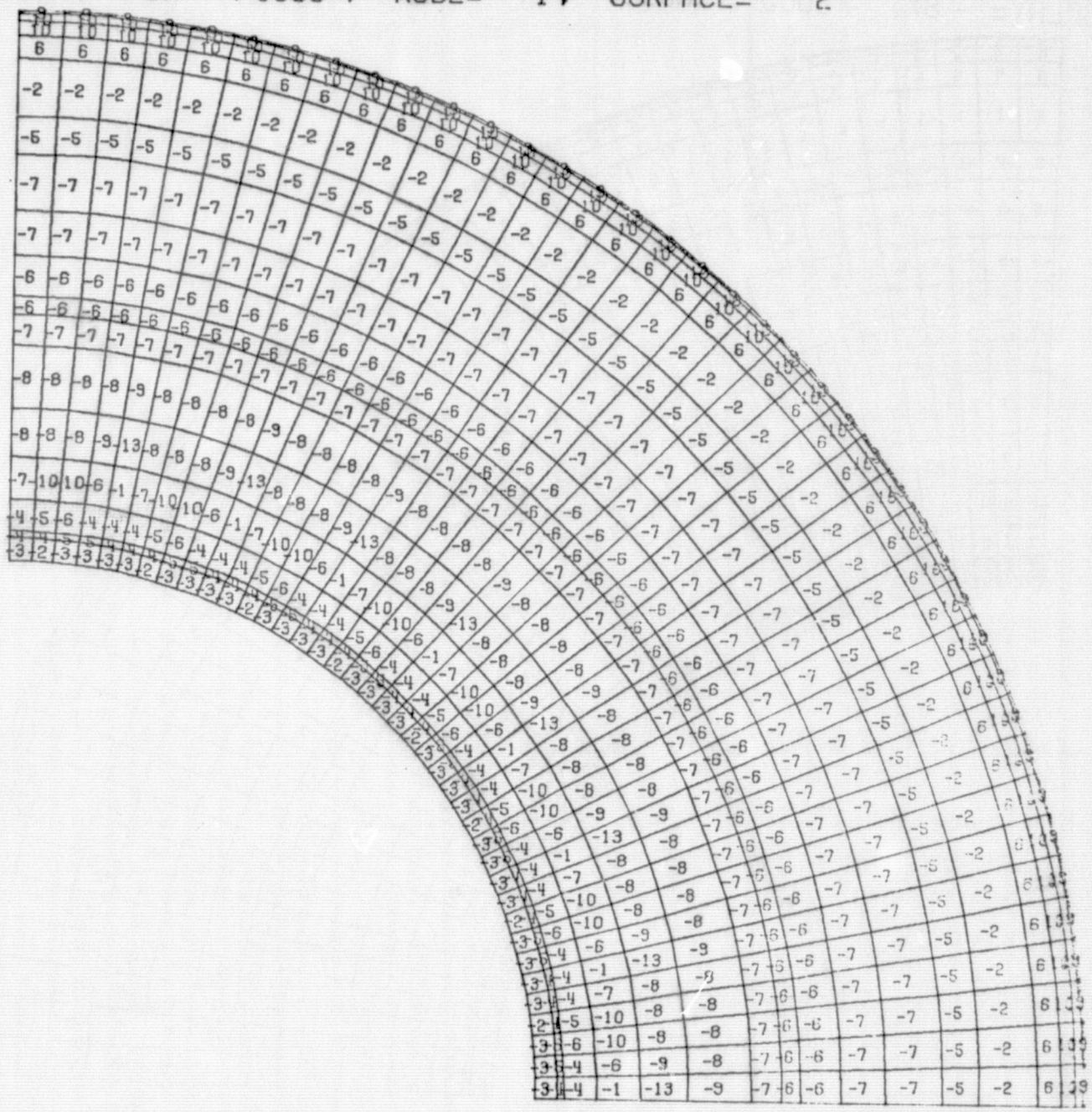
NTF BULKHEAD DOME

0 26
SCALE

FIG. 65

DISPLAY= SX /1000 , NODE= 1, SURFACE= 2

1/1/1

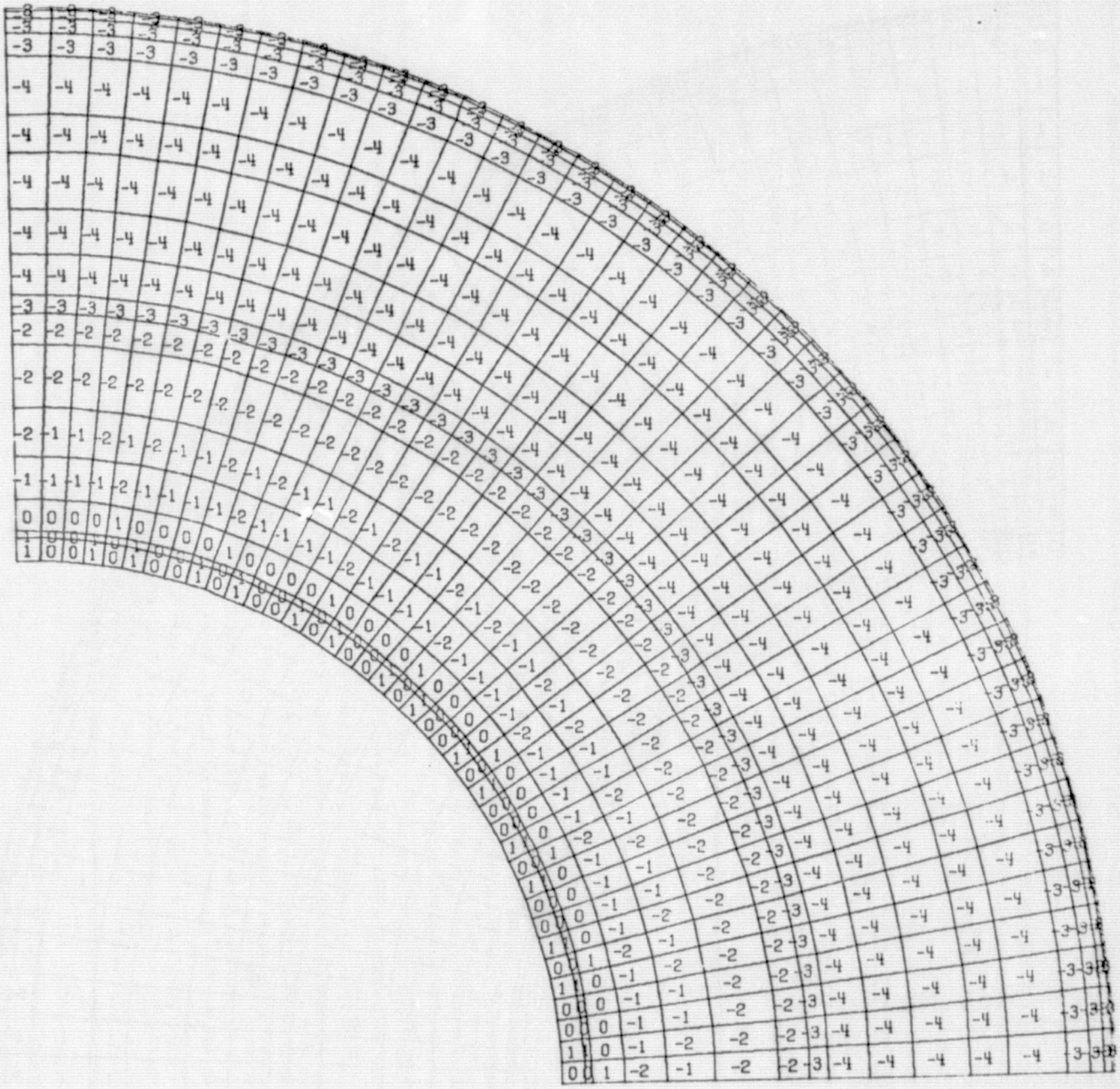


SPEC 3.1

NTF BULKHEAD DOME

0 SCALE 26

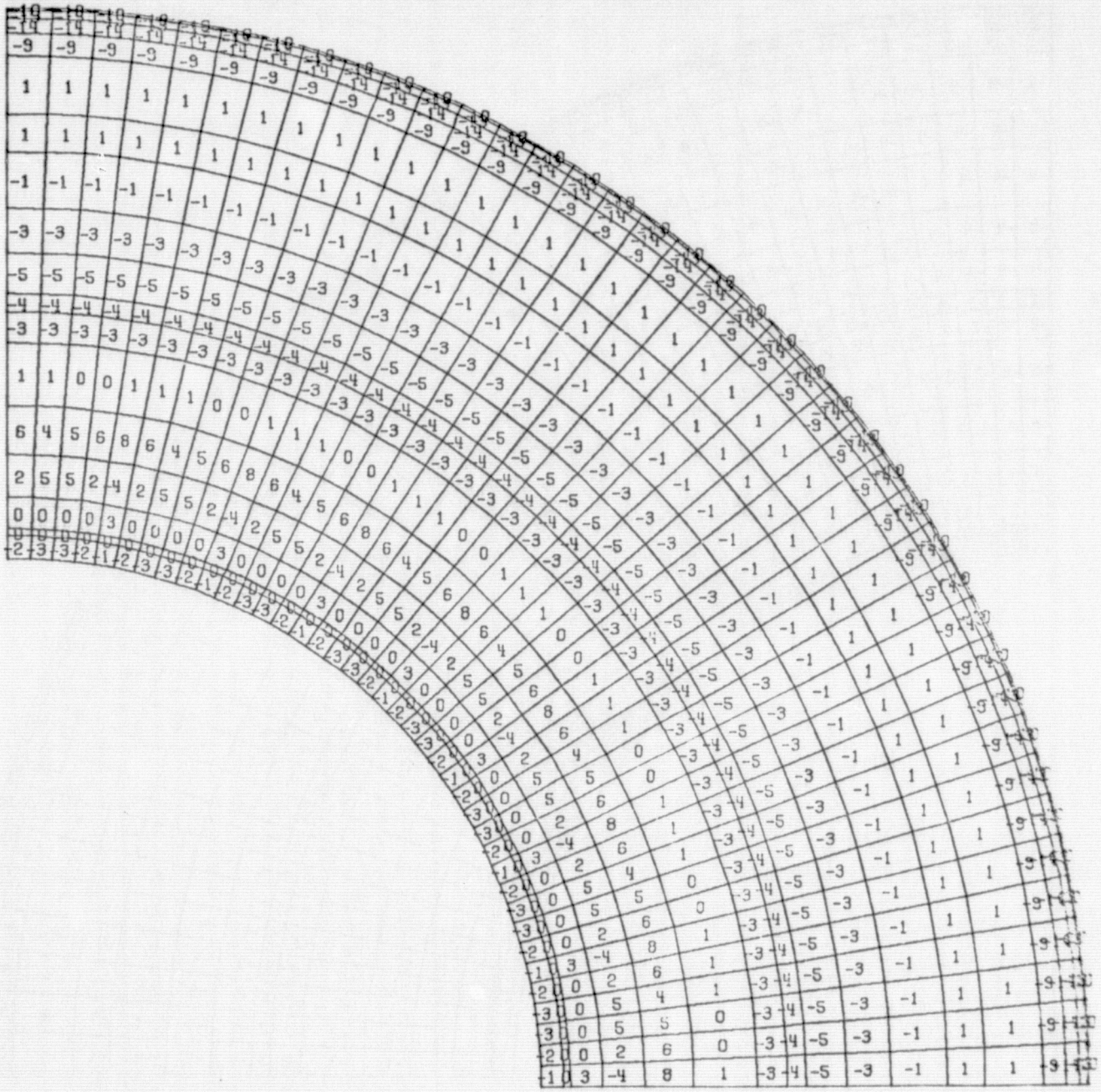
DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0



SPEC NTF BULKHEAD
3.1 DOME

FIG. 67

DISPLAY= SY /1000 , NODE= 1, SURFACE= 1



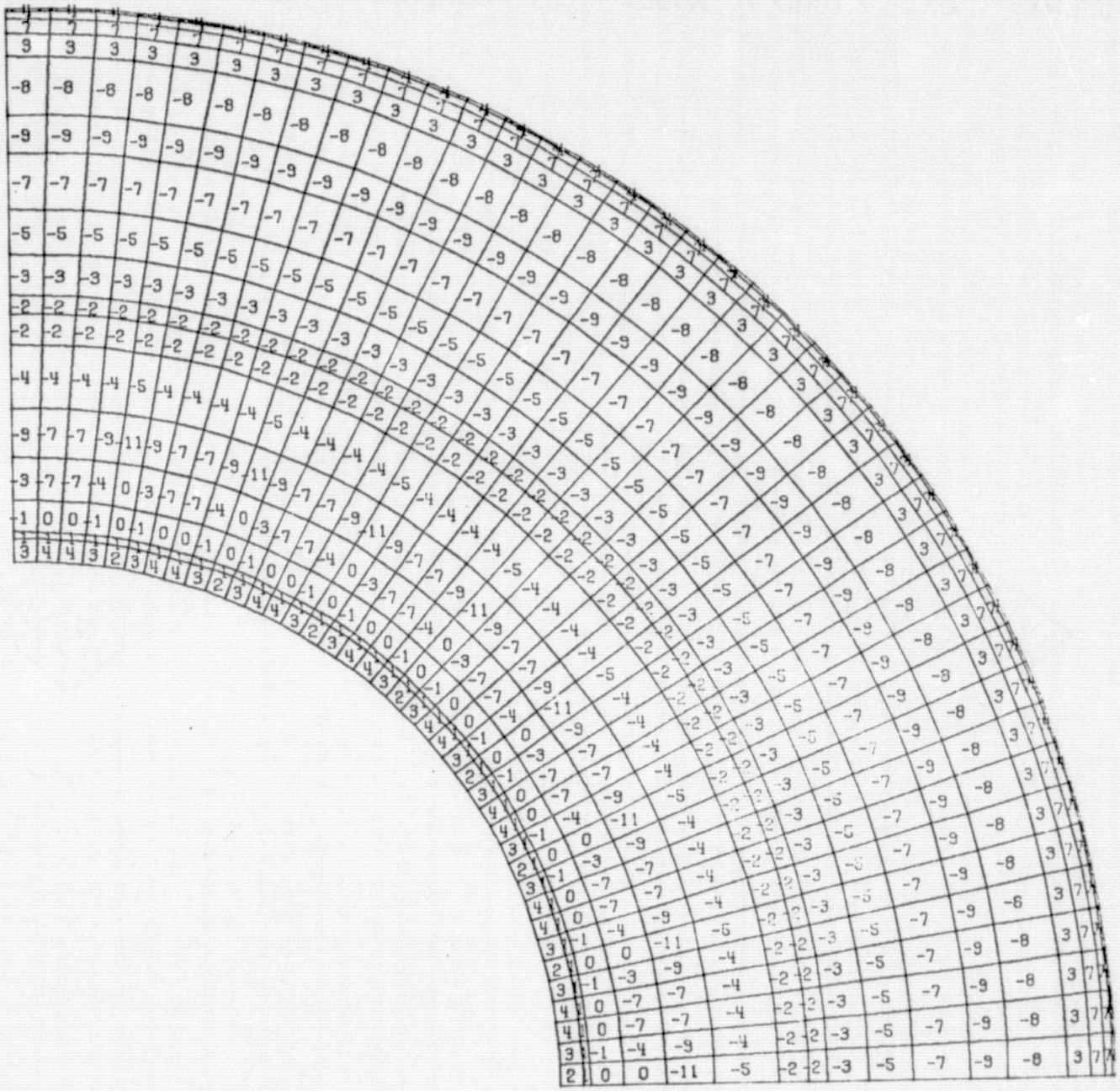
SPEC 3.1 NTF BULKHEAD DOME

0 26
SCALE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2



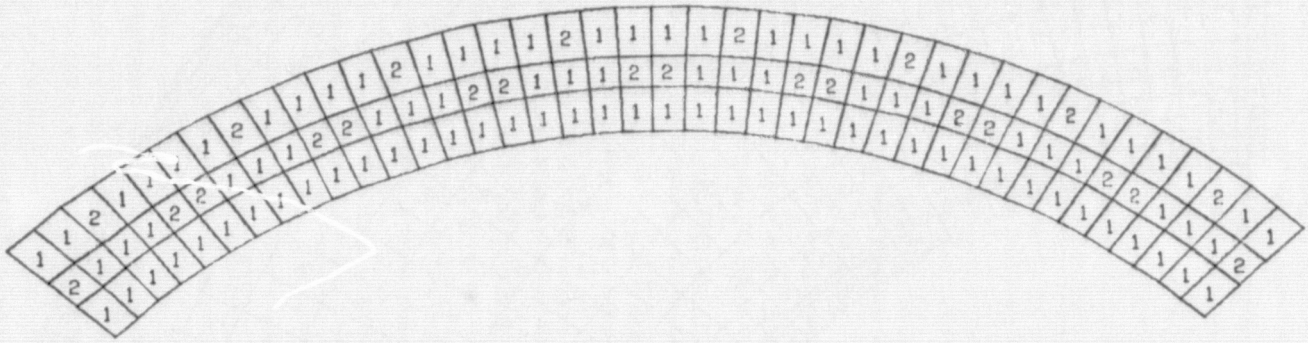
SPEC 3.1 NTF BULKHEAD DOME

0 26
SCALE

FIG. 69

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0



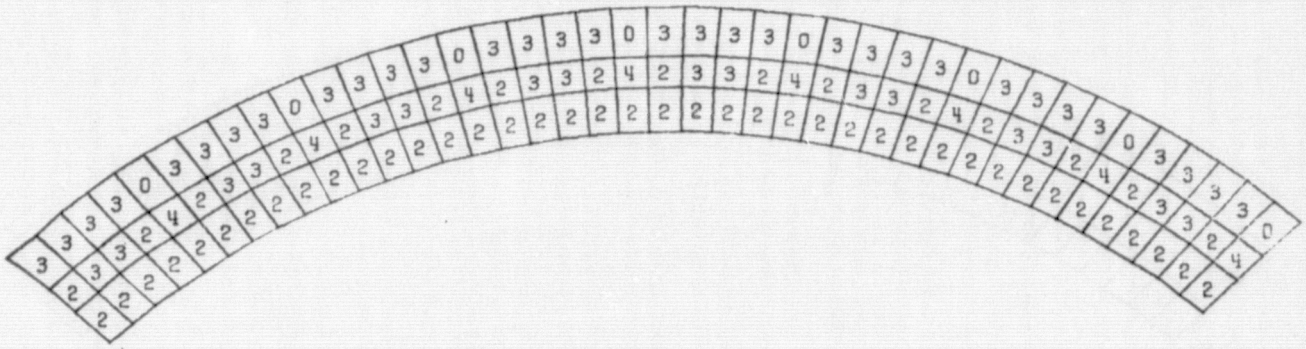
SPEC 2.1

NTF BULKHEAD FLANGE SURFACE

0 21
SCALE

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1



SPEC 2.1

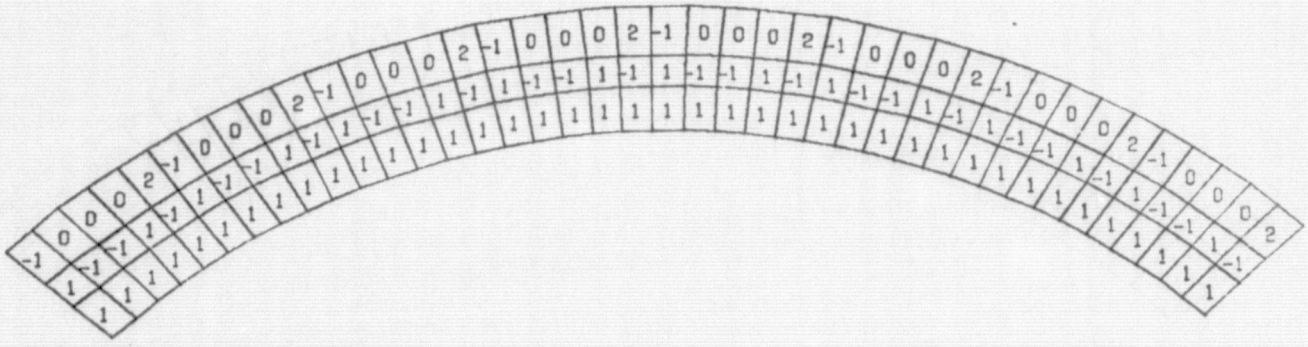
NTF BULKHEAD FLANGE SURFACE

0 SCALE 21

FIG. 71

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2



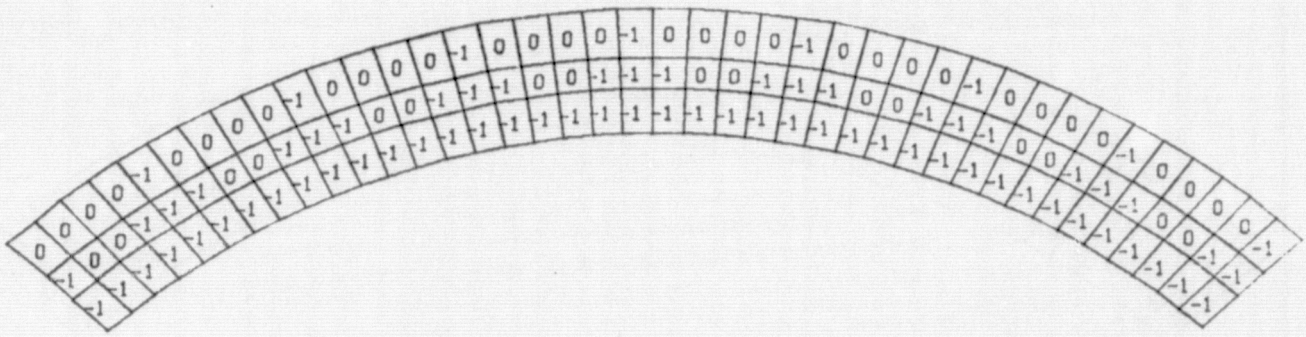
SPEC 2.1
NTF BULKHEAD FLANGE SURFACE

0 21
SCALE

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0

1/1/1



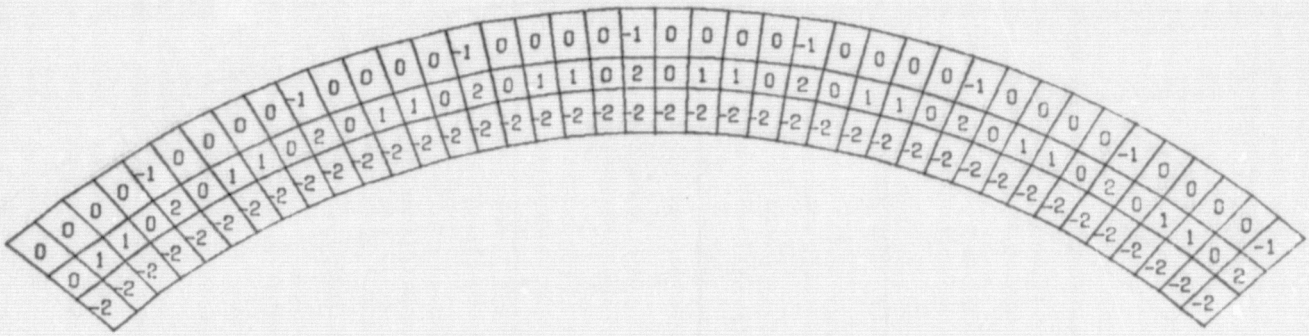
SPEC 2.1 NTF BULKHEAD FLANGE SURFACE

0 SCALE 21

FIG. 73

DISPLAY= SY /1000 , NODE= 1, SURFACE= 1

1/1/1



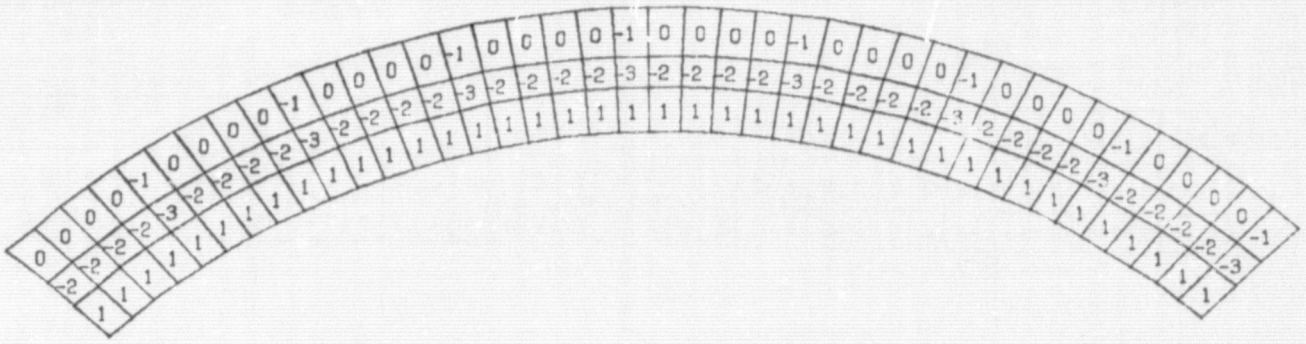
SPEC 2.1 NTF BULKHEAD FLANGE SURFACE

0 21
SCALE

FIG. 74

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2



SPEC 2.1

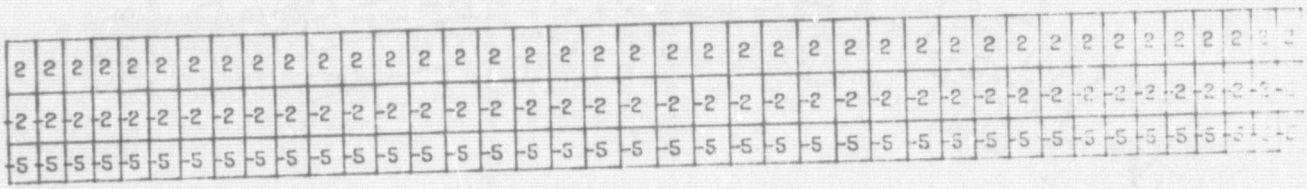
NTF BULKHEAD FLANGE SURFACE

0 SCALE 21

FIG. 75

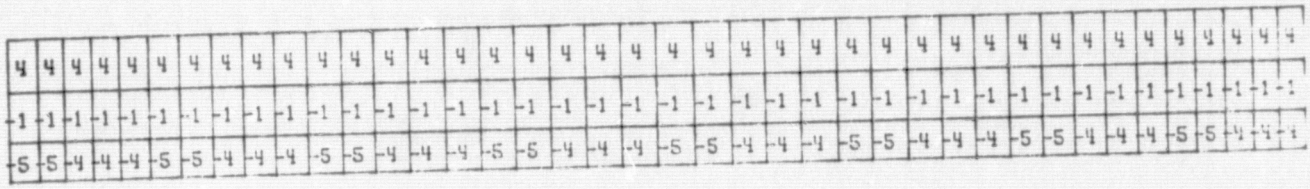
1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0


2 2 2

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1



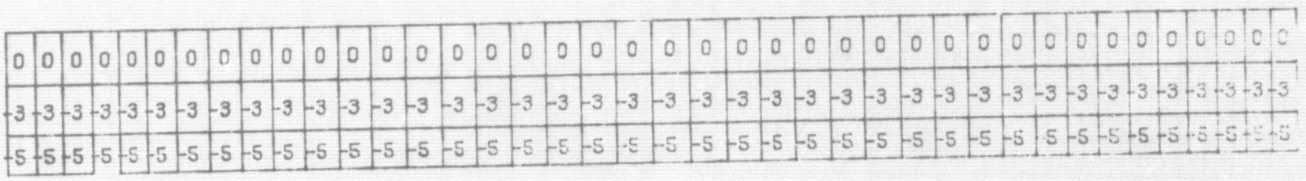
SPEC 10.1 NTF BULKHEAD HATCH OPENING

0 18 SCALE

FIG. 77

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2

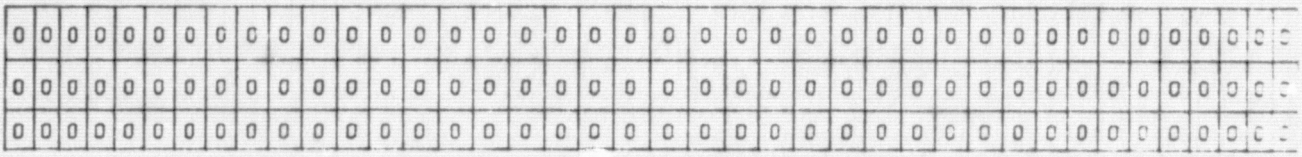

0 0 0

)

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0

1/1.1

)



SPEC 10.1 NTF BULKHEAD HATCH OPENING

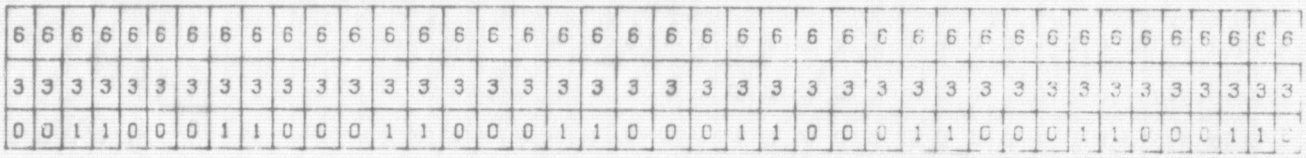
0 SCALE :8

)

FIG. 7?

DISPLAY= SY /1COO , NODE= 1 , SURFACE= 1

1/1/1

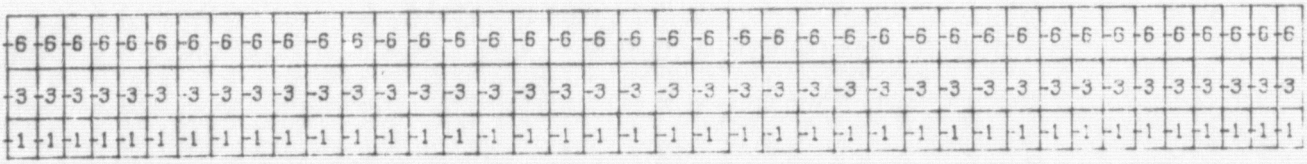

6 6 6

)

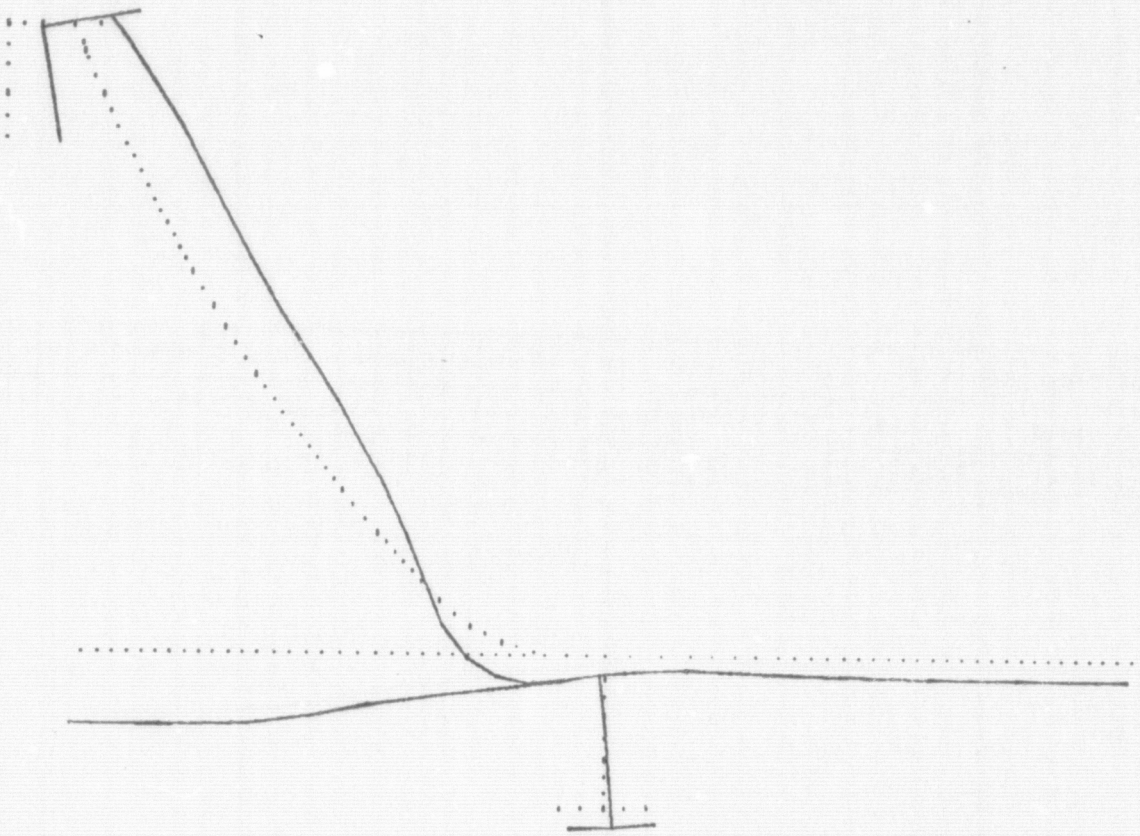
1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2

)


-6 -6 -6 -

1/1

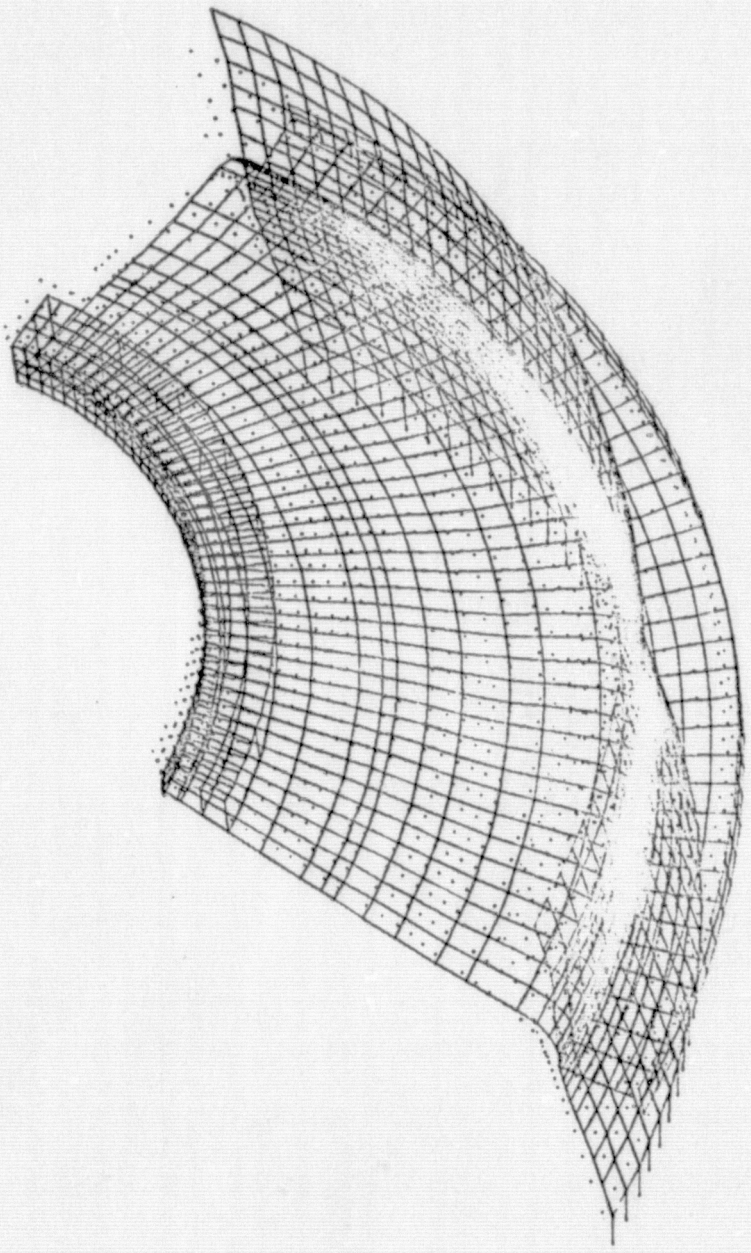


SPEC 12.1

NTF BULKHEAD
CROSS-SECTION VIEW

0 SCALE 27

1/1/1



SPEC
1.1

NTF BULKHEAD

0 44
SCALE

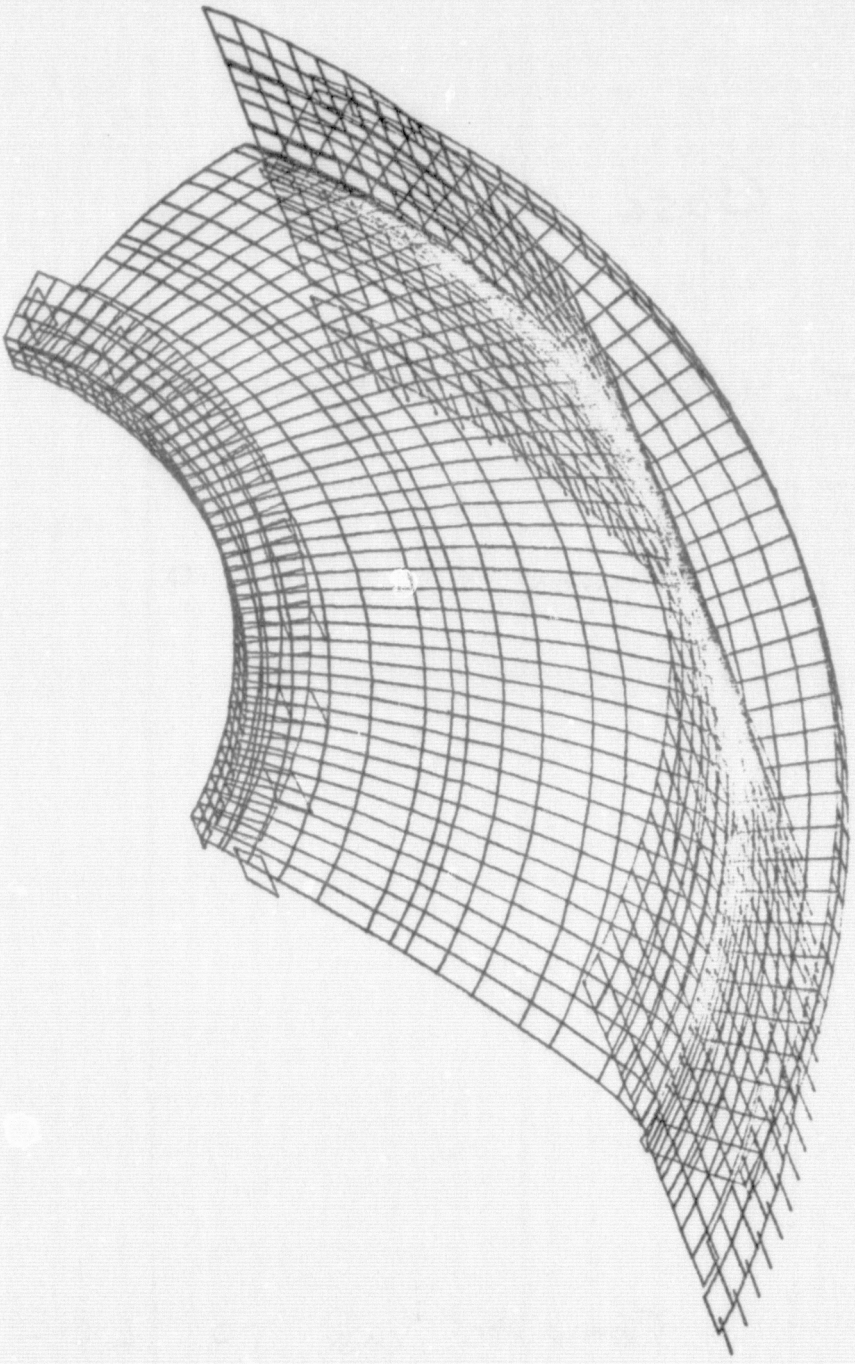
FIG. 83

Case 3

Full pressure stress plots

Figures 84 thru 110

Compute run no. LGL



NTF BULKHEAD

0 41
SCALE

FIG. 84

)

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0

12	12	12	11	10	9	7	6	6	5	5	6	6	9	15	18	20	20
12	12	12	11	10	9	7	6	6	5	5	5	6	9	15	18	20	20
12	12	12	11	10	9	7	6	6	5	5	5	6	9	15	18	20	20
12	12	12	11	10	9	7	6	6	5	5	5	6	9	15	18	20	20
12	12	12	11	10	9	7	6	6	5	5	6

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1

12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20
12	12	11	10	9	8	7	7	7	7	6	2	4	8	14	19	21	20

SPEC _NIF. BULKHEAD

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

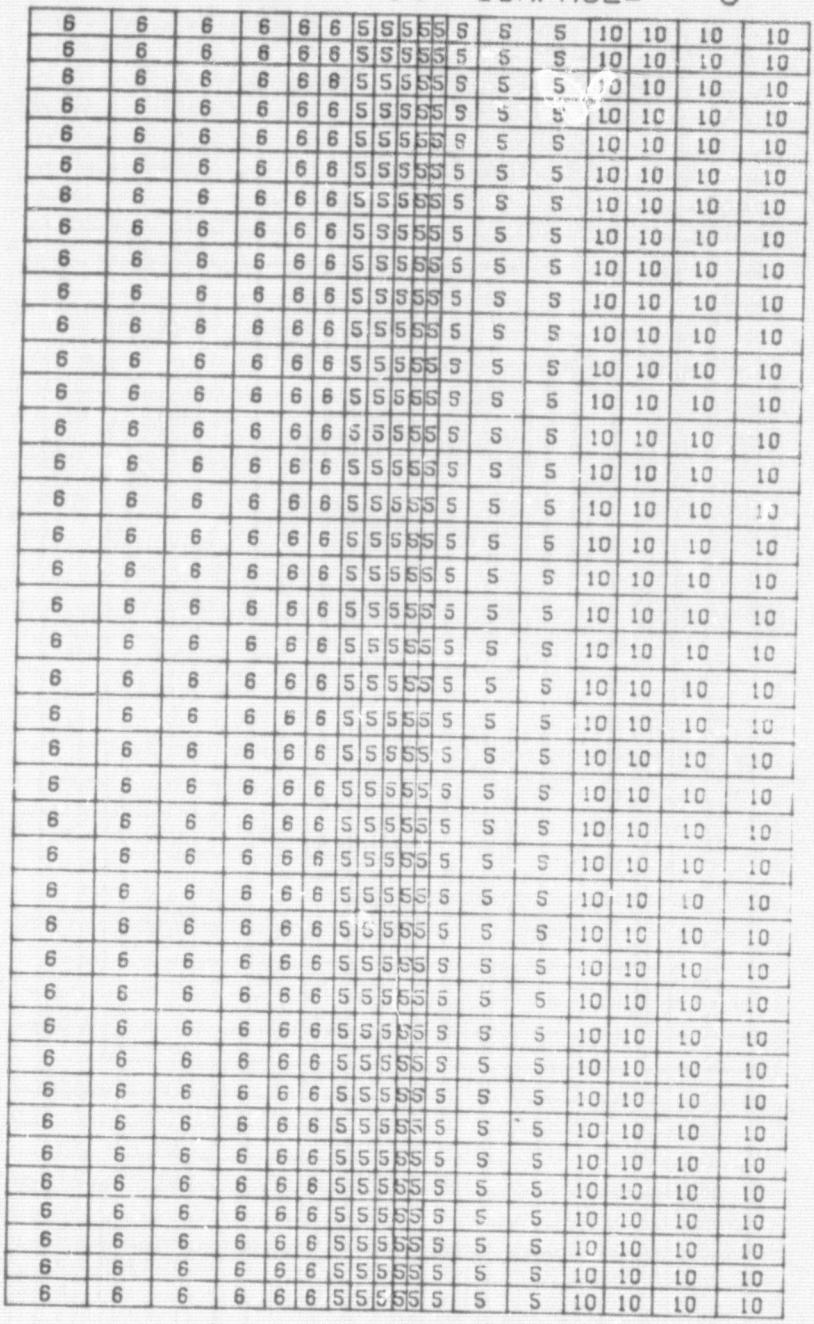
1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2

12	12	12	12	11	9	7	5	4	4	4	8	7	9	15	17	19	20

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0

1/1/1



SPEC 5.1 NIF BULKHEAD SHELL

0 SCALE 36

FIG 28

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1

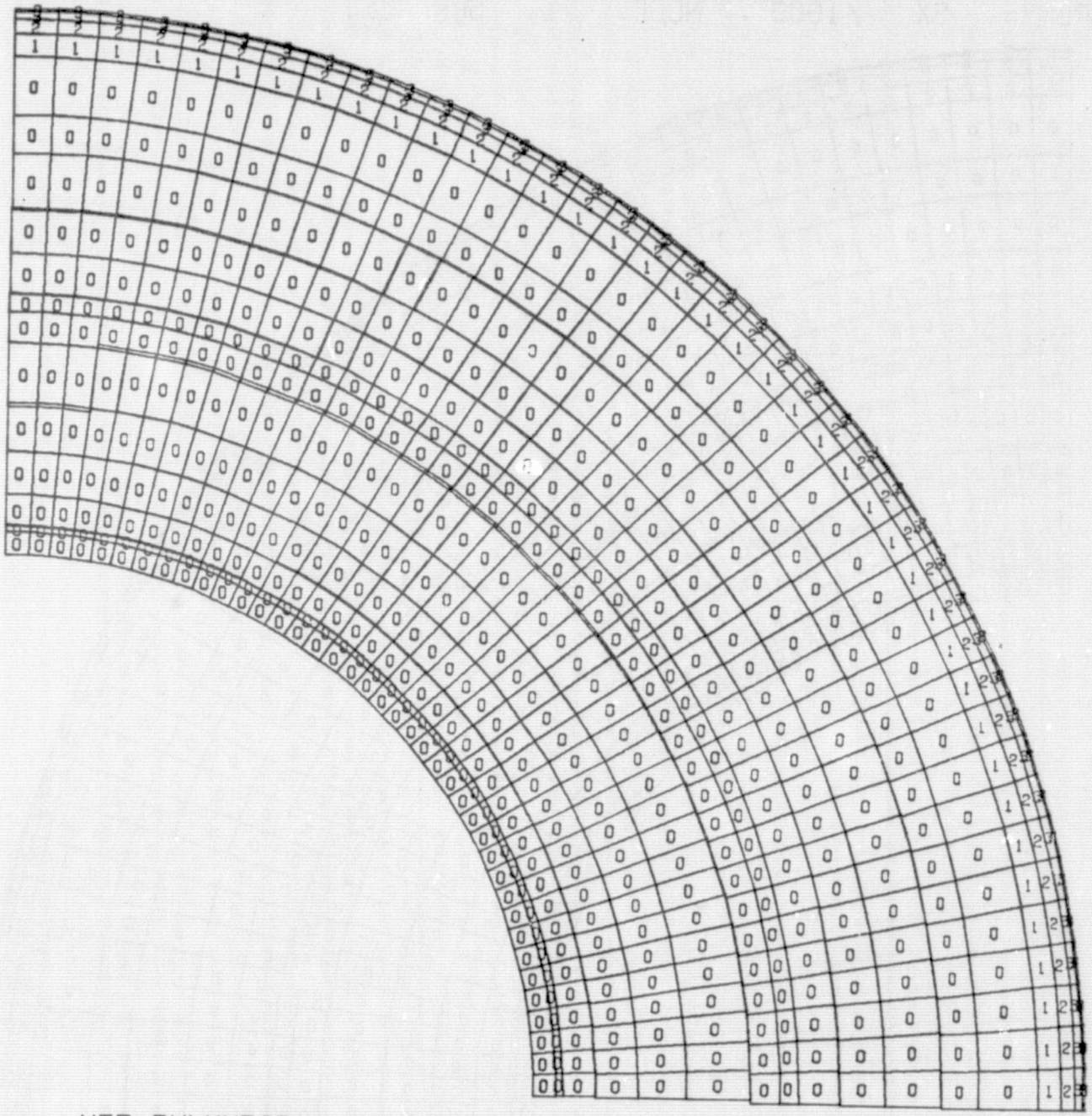
6	6	5	4	4	5	6	8	1	1	9	8	-4	0	3	9	13	12	10

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2

6	6	7	8	8	7	4	2	1	12	14	10	7	11	7	8	10

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0

1/1/1



SPEC 3.1

NTF BULKHEAD DOME

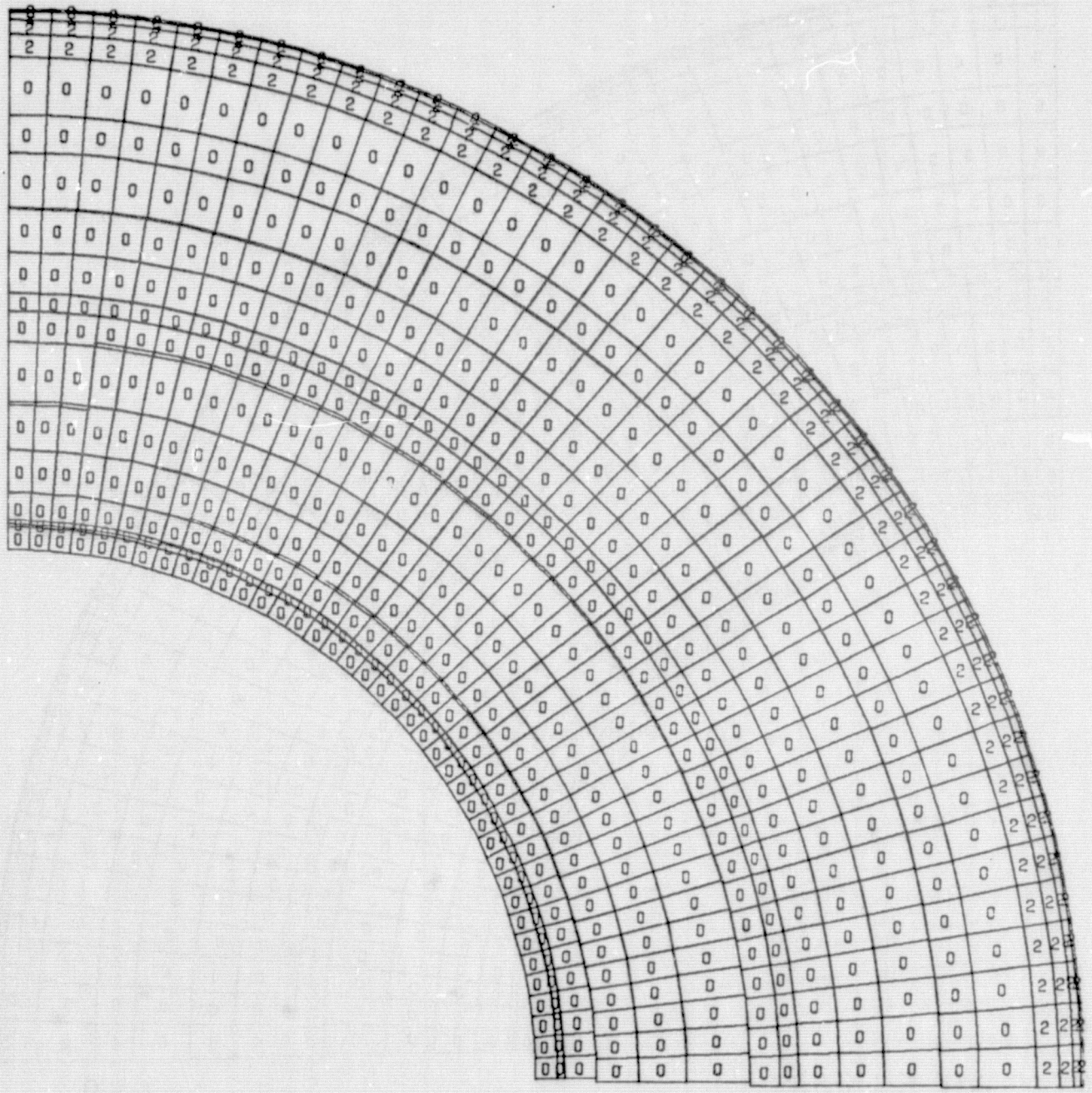
0 26

SCALE

FIG. 91

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1



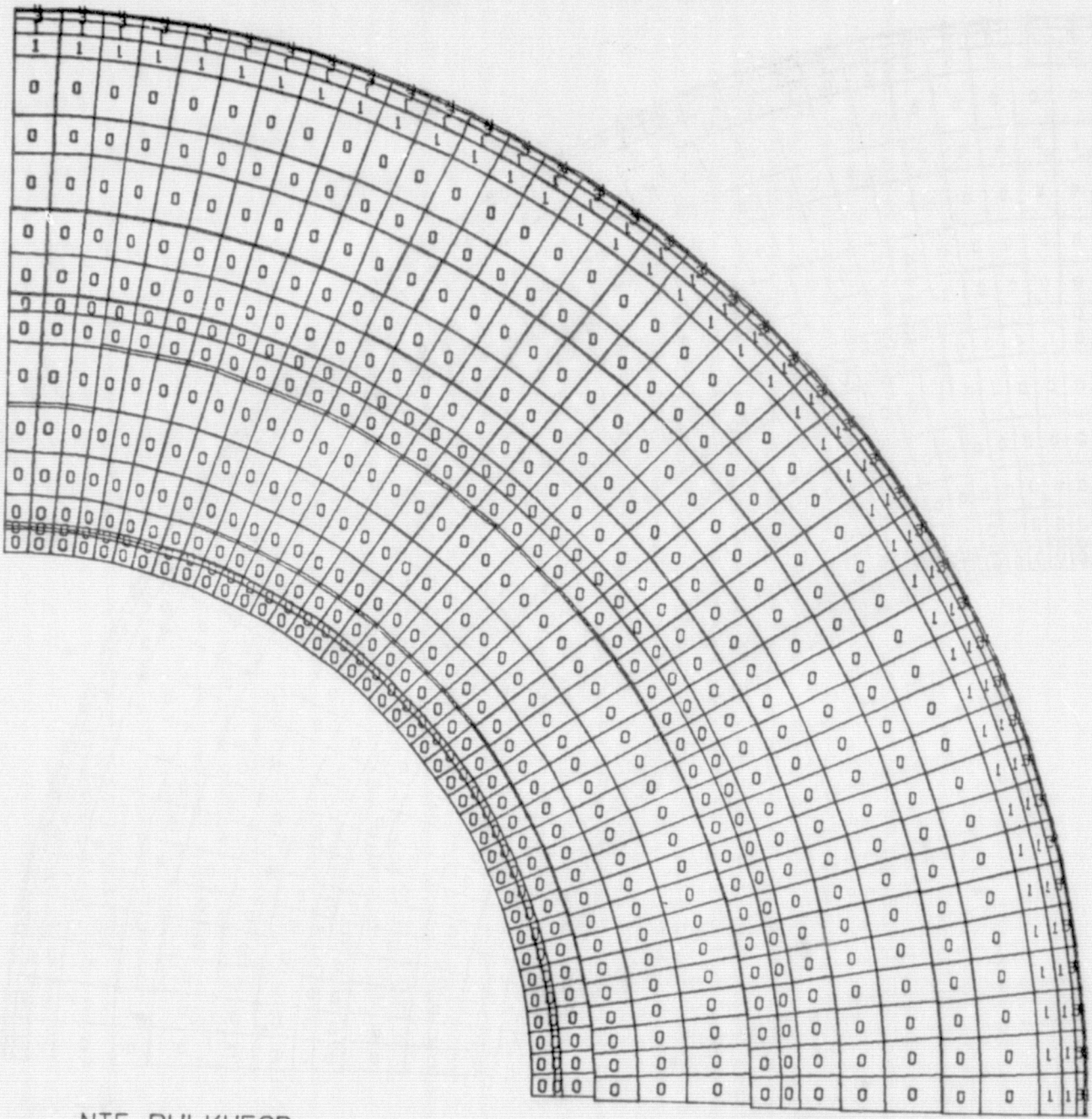
SPEC 3.1

NTF BULKHEAD DOME

0 26
SCALE

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2

1/1/1



SPEC
)1

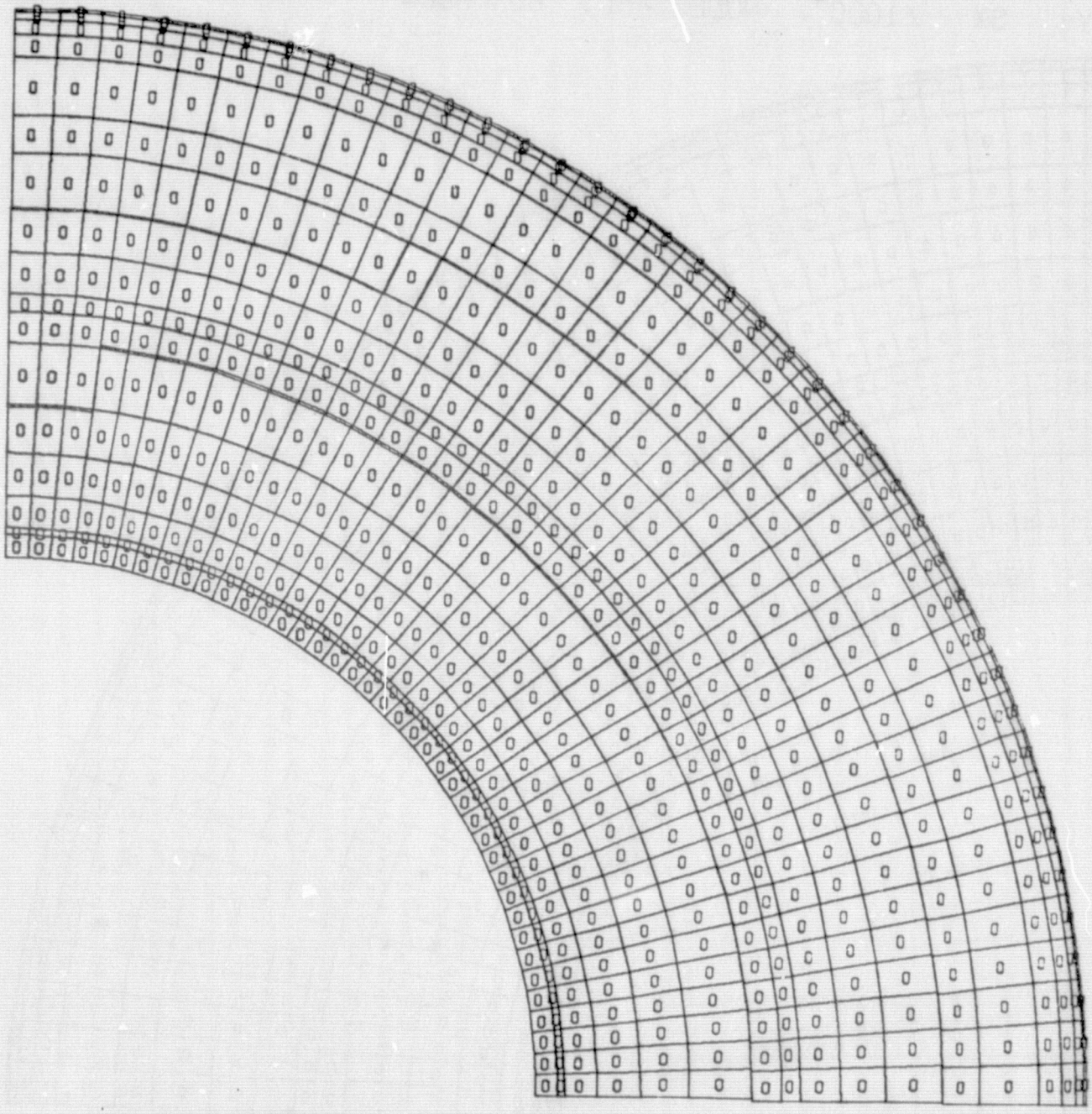
NTF BULKHEAD
DOME

0 26
SCALE

FIG. 93

)ISPLAY= SY /1000 , NODE= 1, SURFACE= 0

1/1/1



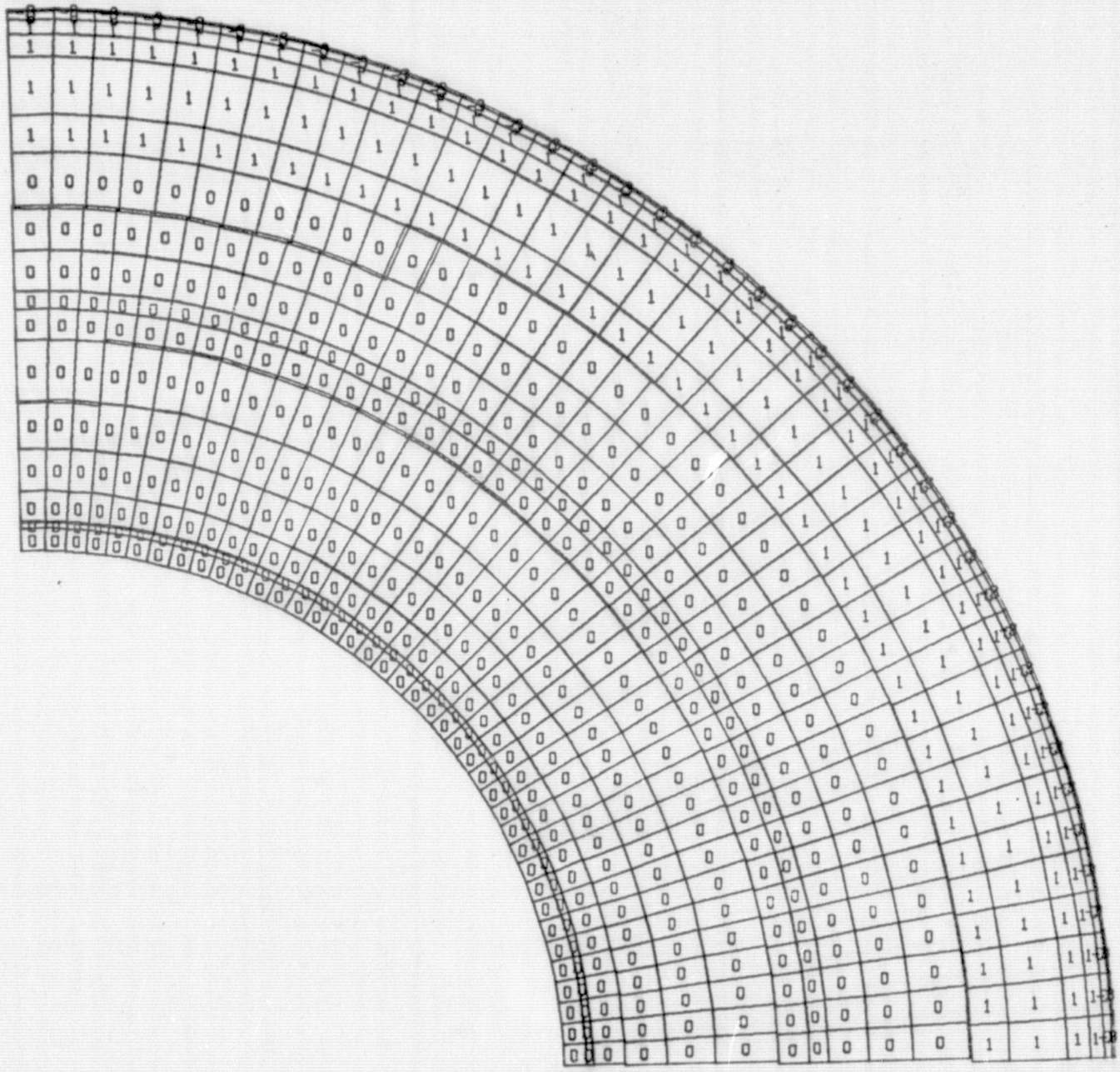
SPEC
2.1

NTF BULKHEAD
DOME

0 26
SCALE

1/1/1

DISPLAY= SY /1000 , NODE= 1, SURFACE= 1



0 26
SCALE

SPEC
)3.1

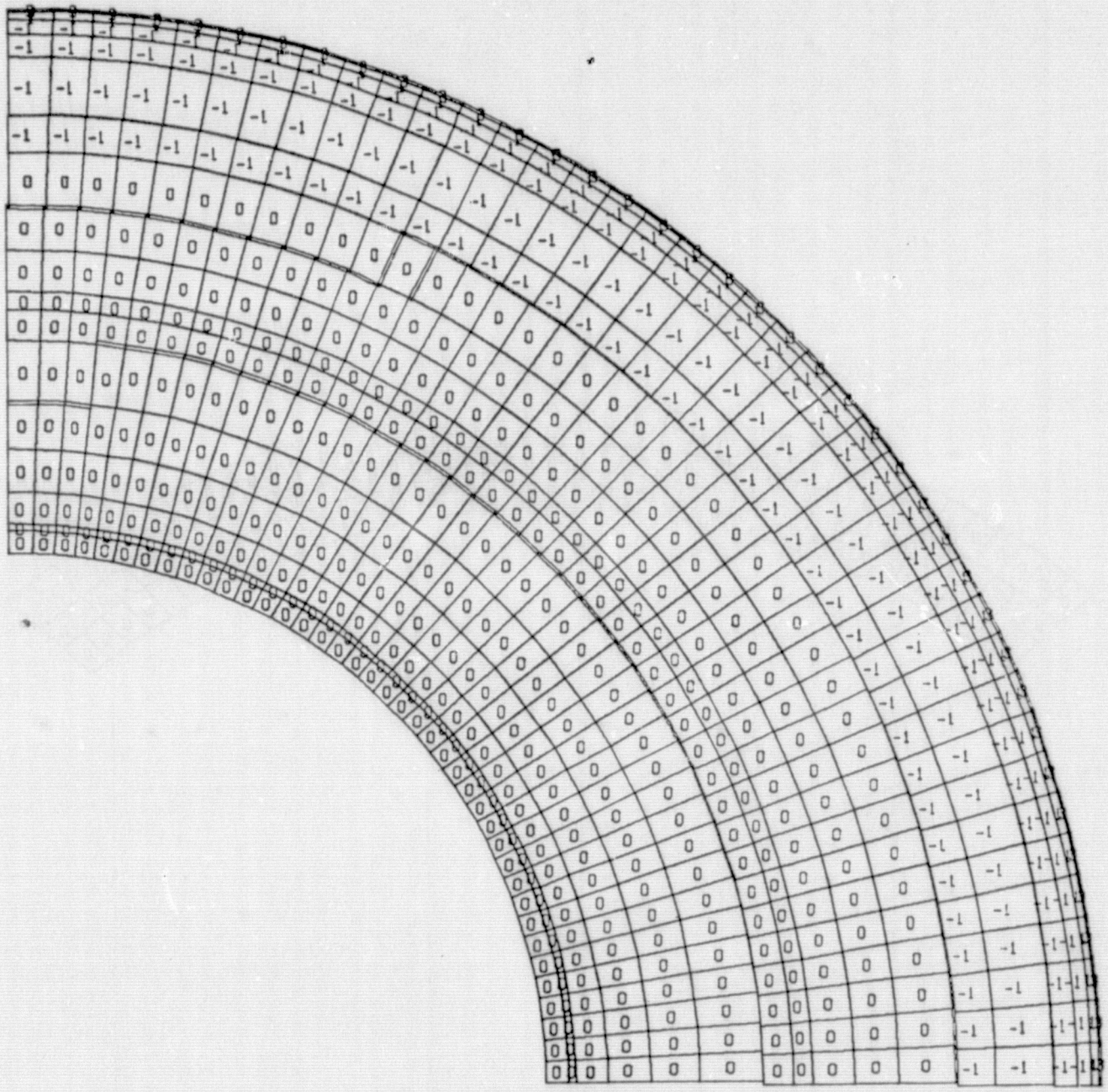
NTF BULKHEAD
DOME

PRECEDING PAGE BLANK NOT FILMED

FIG. 96

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2



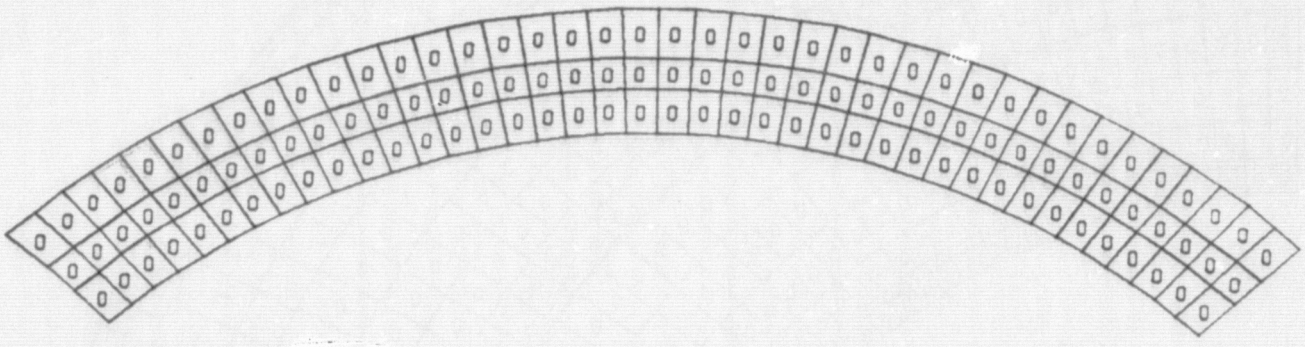
SPEC 3.1

NTF BULKHEAD DOME

0 26
SCALE

FIG. 97

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0 1/1/1



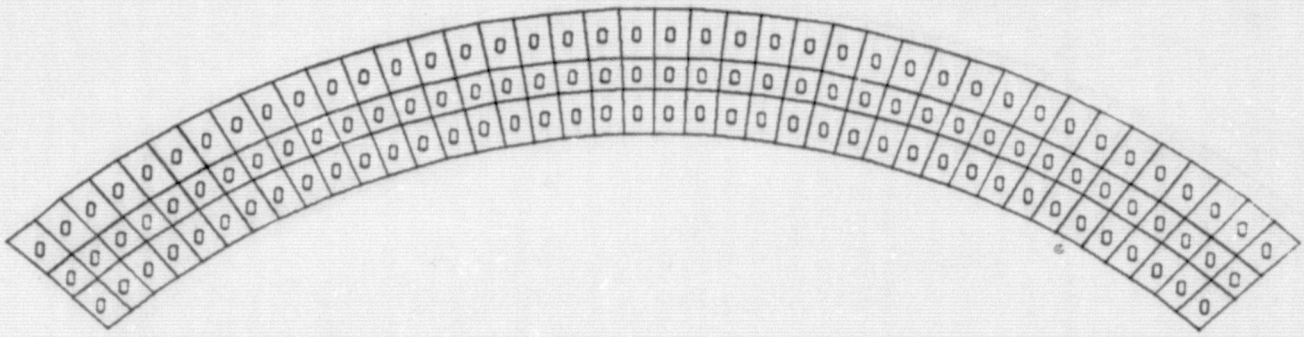
SPEC 2.1 NTF BULKHEAD FLANGE SURFACE

0 21
SCALE

Fig 99

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1

1/1/1



SPEC 2.1

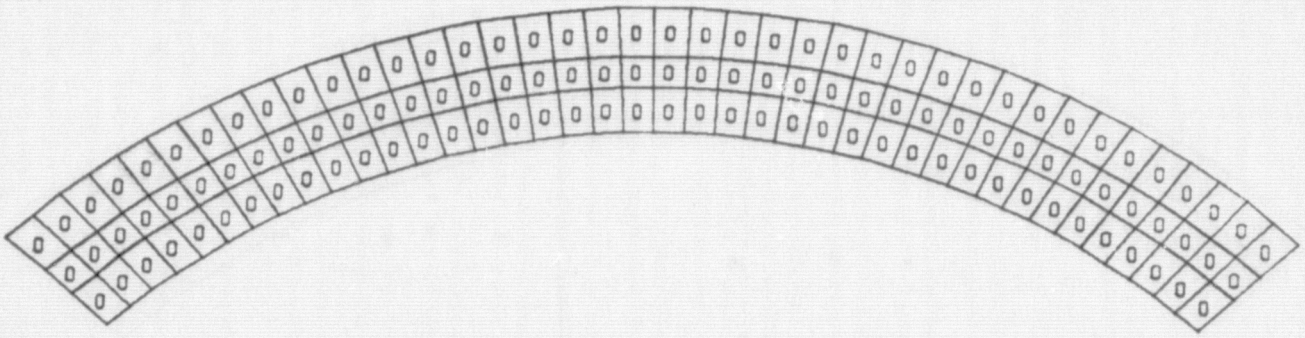
NTF BULKHEAD FLANGE SURFACE

0 21 SCALE

FIG. 99

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2

1/1/1



SPEC 2.1

NTF BULKHEAD FLANGE SURFACE

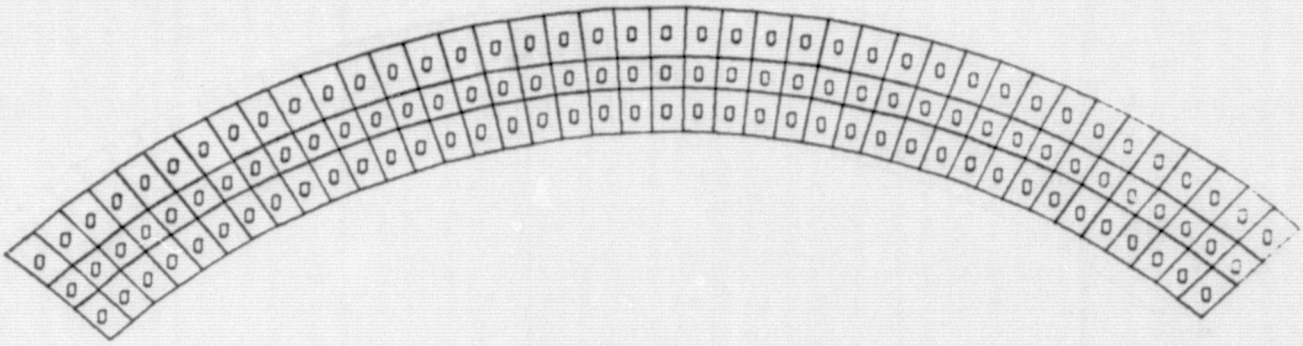
0 21
SCALE

FIG 100

)

1/1/:

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0



SPEC
2.1

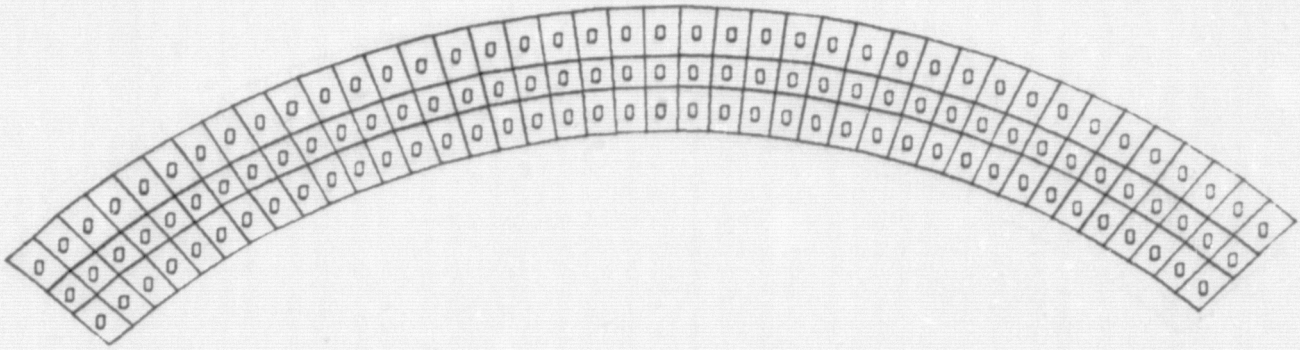
NTF BULKHEAD
FLANGE SURFACE

0 21
SCALE

FIG. 101

1/1/1

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 1



0 21
SCALE

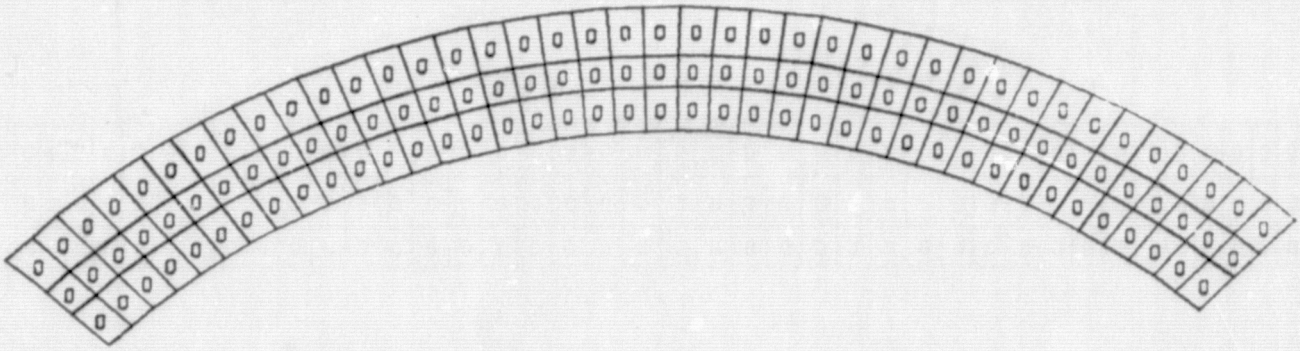
SPEC
2.1

NTF BULKHEAD
FLANGE SURFACE

)

1/1/1

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 2



0 21
SCALE

SPEC
2.1
)

NTF BULKHEAD
FLANGE SURFACE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

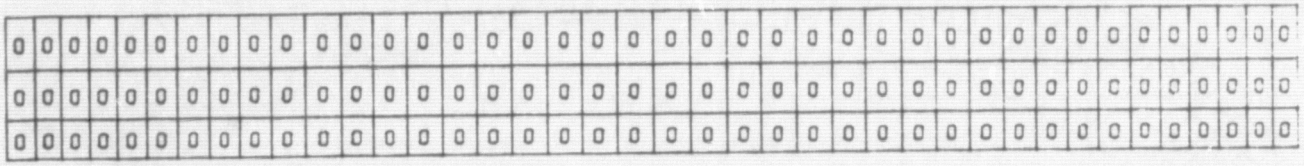
FIG. 103

)

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0

)



SPEC '0.1
)

NTF BULKHEAD
HATCH OPENING

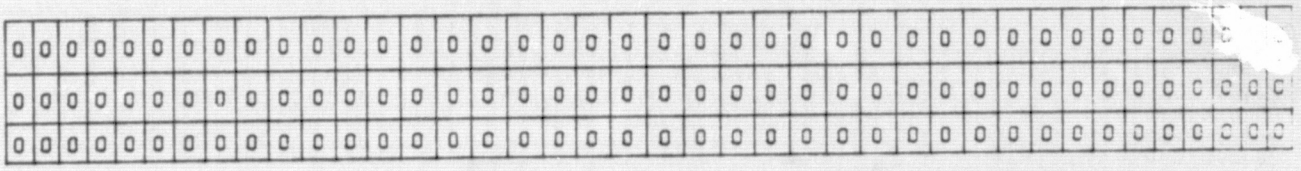
0 18
SCALE

)

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1

)



SPEC 10.1
)

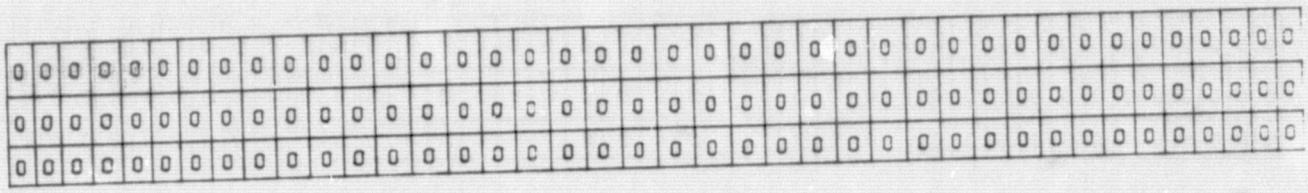
NTF BULKHEAD
HATCH OPENING

0 18
SCALE

FIG. 105

1/1/1

DISPLAY= SX /1000 , NODE= 1, SURFACE= 2



SPEC
)10.1

NTF BULKHEAD
HATCH OPENING

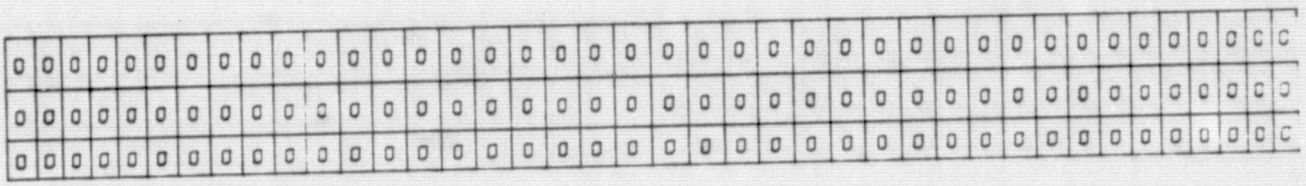
0 18
SCALE

)

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0

)



SPEC 10.1 NTF BULKHEAD HATCH OPENING

0 18
SCALE

)

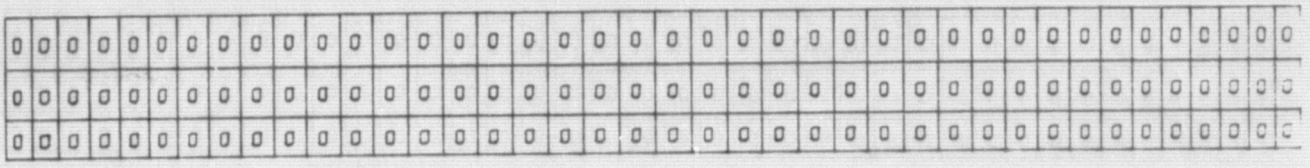
FIG. 107

)

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1

)



SPEC
10.1

NTF BULKHEAD
HATCH OPENING

0 18
SCALE

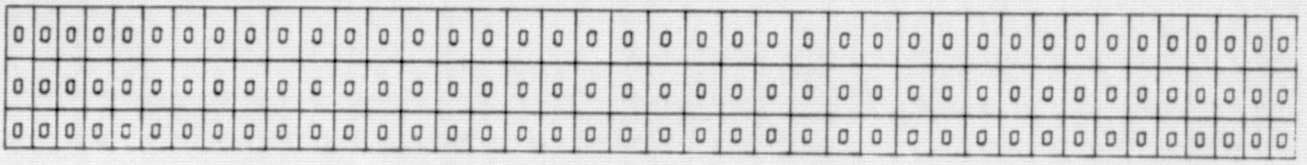
)

)

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2

1/1/1

)



SPEC
10.1

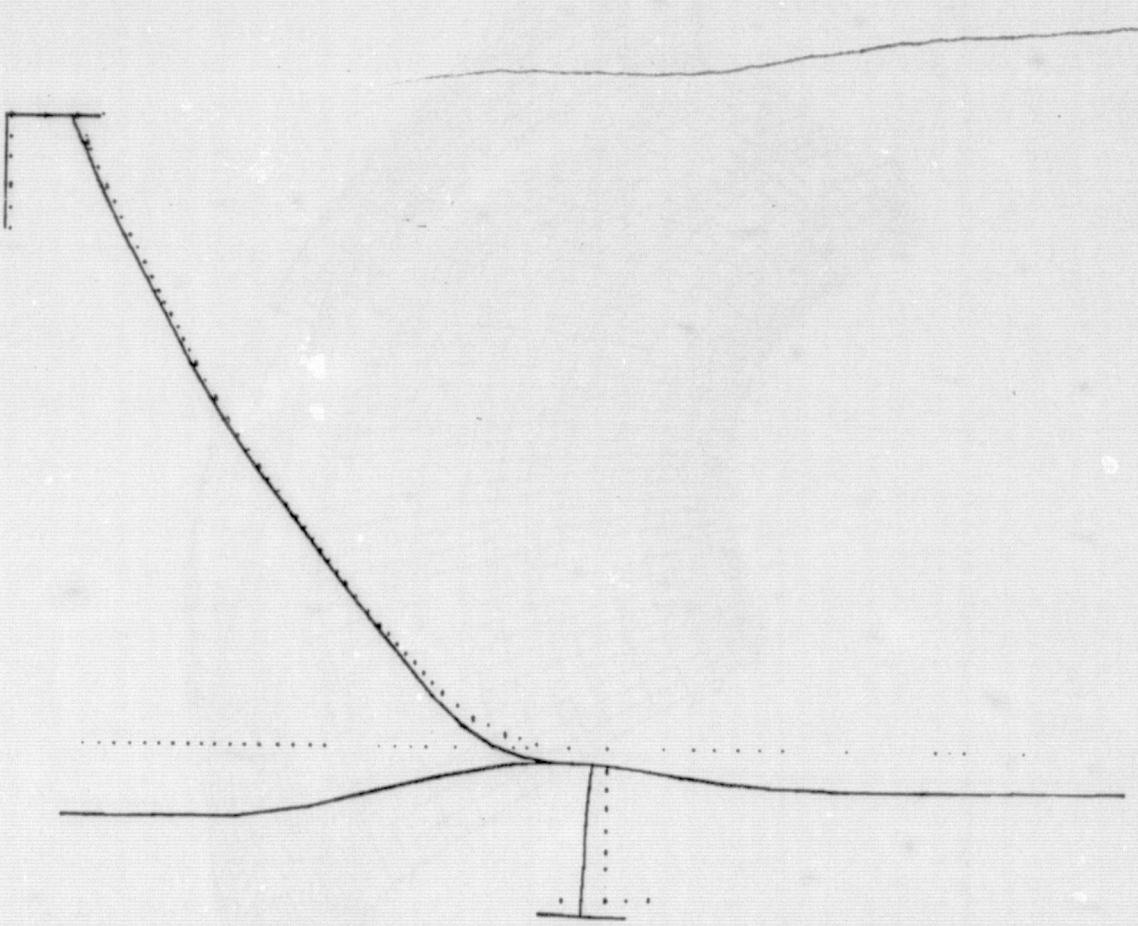
NTF BULKHEAD
HATCH OPENING

0 18
SCALE

)

FIG. 108

1/1/1



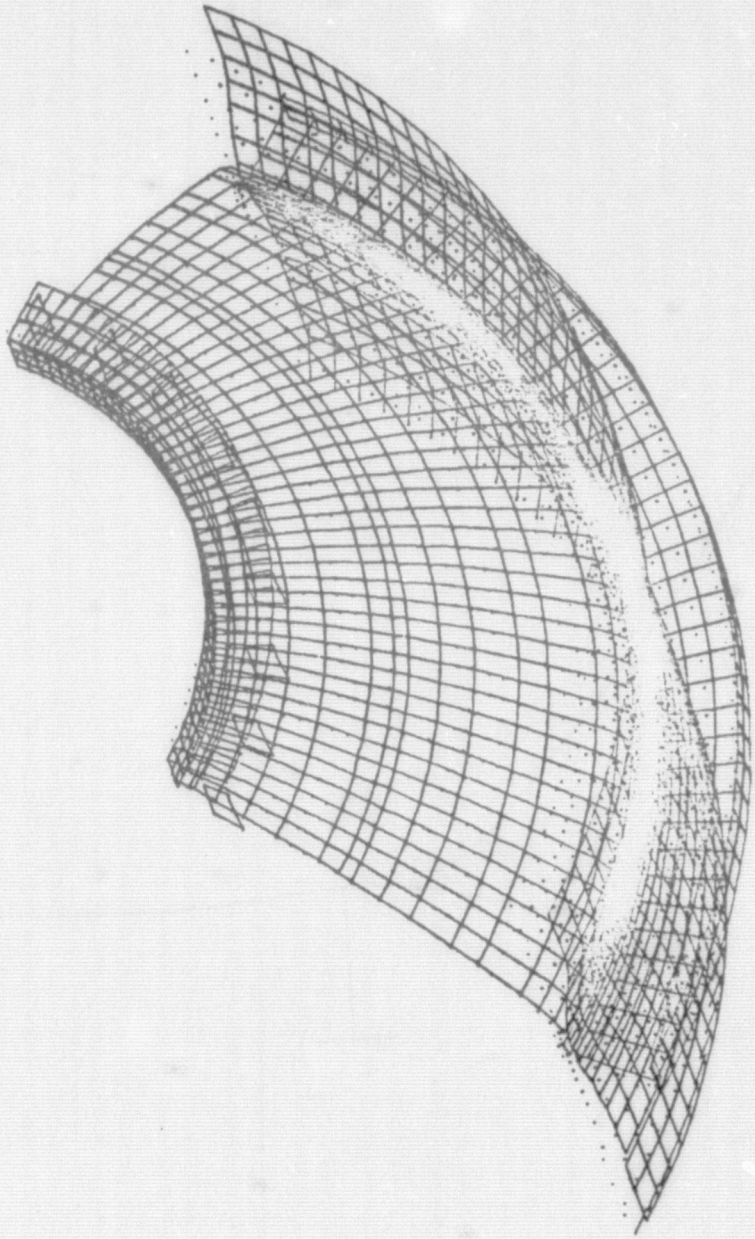
SPEC

NIF_BULKHEAD

0 27

FIG. 109

1/1/1



SPEC NTF BULKHEAD

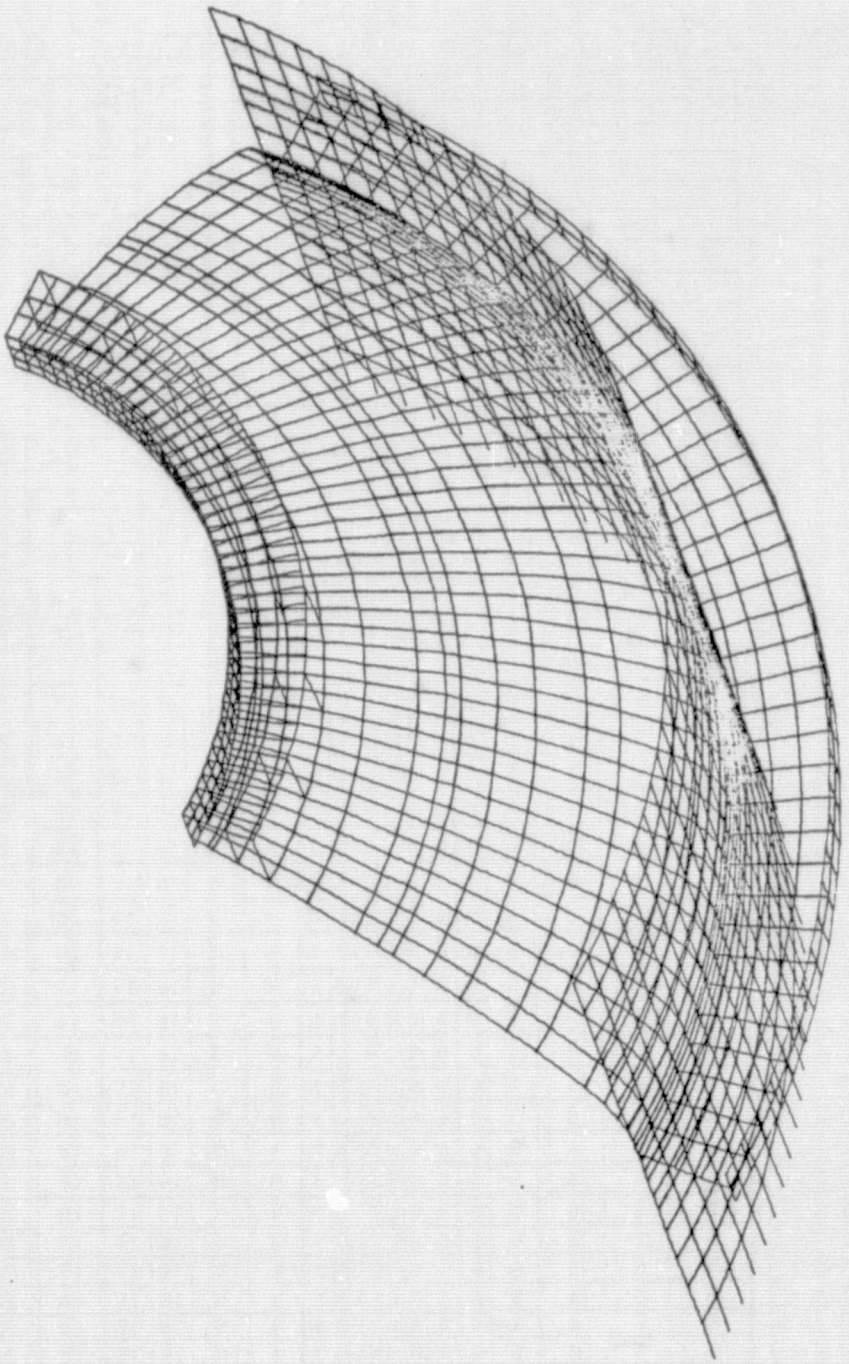
0 44

Case 6

Valve open steady state temp. dist.
stress plots.

Figures 111 Thru 137

Computer run no. HGF



SPEC 1

NTE BULKHEAD

0 4

SCALE

FIG. 111

DISPLAY= SX /1000 . NODE= 1 . SURFACE= 0

1/1/1

5	5	6	5	6	6	6	6	6	5	8	9	4	8	16	15	18	22

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1

1/1/1

6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22
6	6	6	6	6	6	6	6	6	6	4	2	7	15	16	20	22

SPEC 5.1 NIF BULKHEAD SHELL

0 36
SCALE

FIG 113

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2

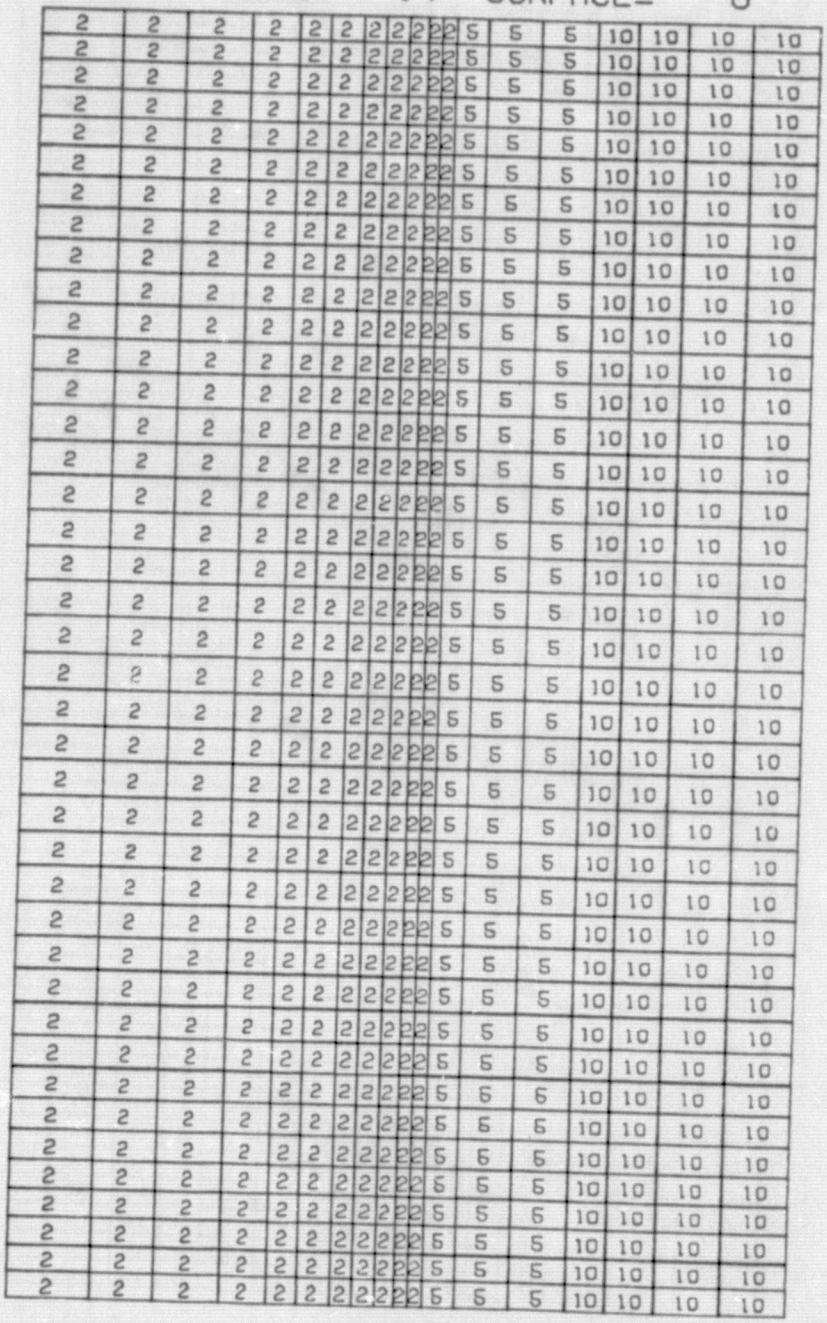
1/1/1

6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22
6	6	6	5	6	6	6	6	6	6	13	7	9	18	13	16	22

SPEC 5.1 NTF BULKHEAD SHELL

0 36
SCALE

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 0 1/1/1



SPEC 5.1 NTF BULKHEAD SHELL

0 SCALE 36

FIG. 115

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1

2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9
2	2	2	2	2	2	1	1	0	-2	-10	-4	1	5	16	16	9

SPEC 5.1 NTF BULKHEAD SHELL

0 SCALE 36

FIG 11G

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 2

1/1/1

3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11
3	3	2	2	2	2	3	4	5	5	7	20	14	9	15	4	4	11

SPEC 5.1 NTF BULKHEAD SHELL

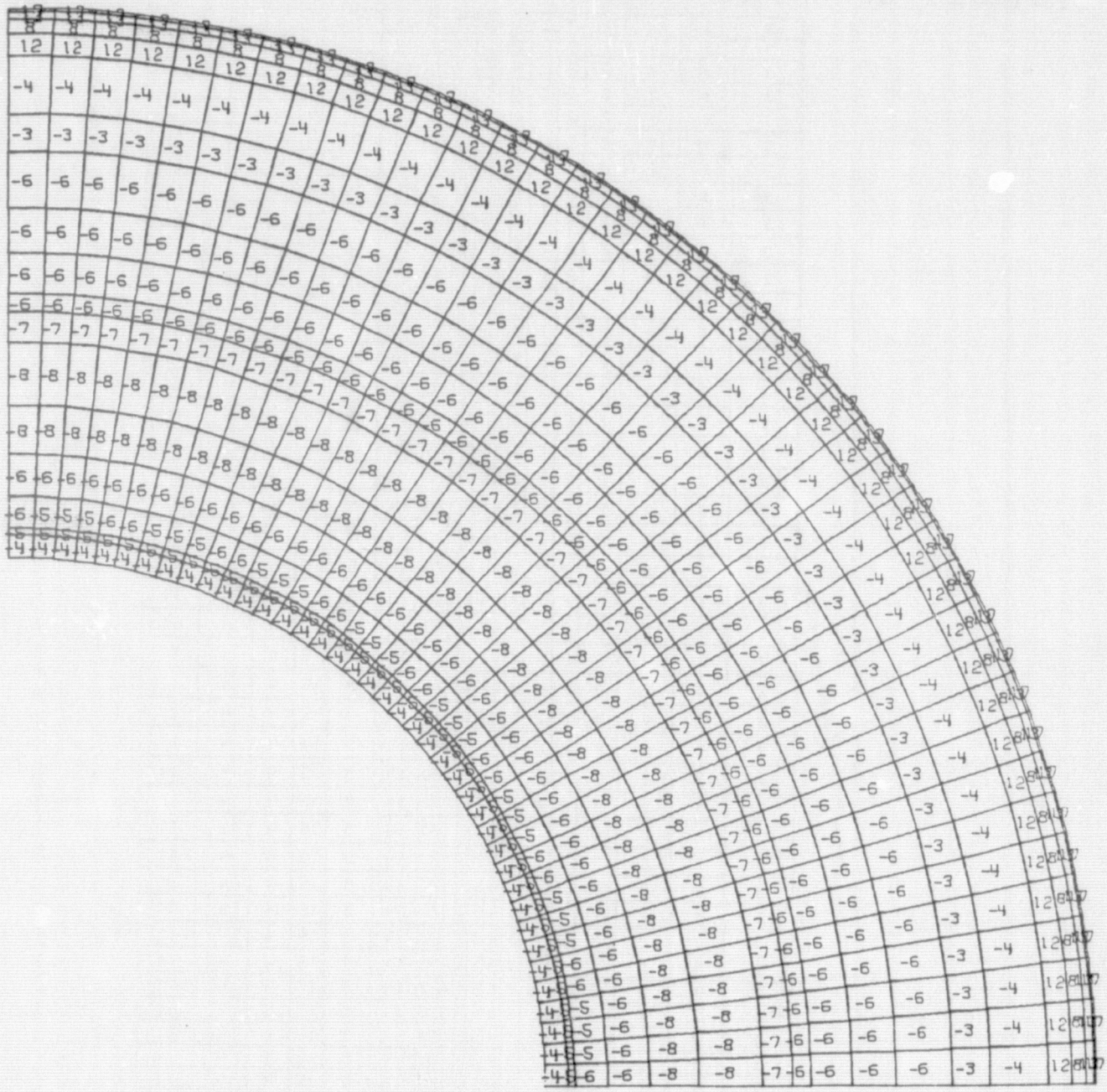
0 SCALE 36

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

FIG. 117

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0



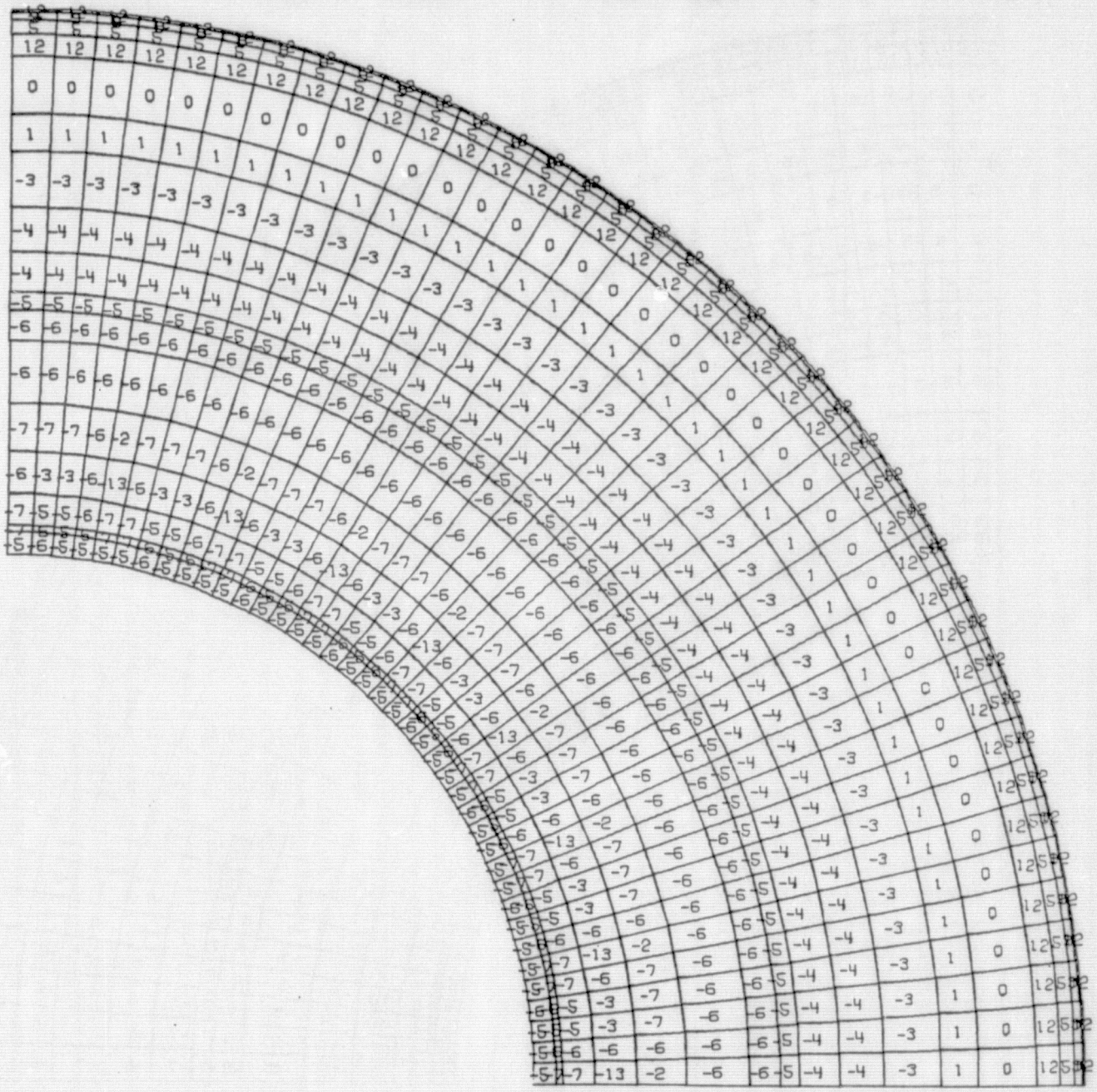
SPEC 3.1

NTF BULKHEAD DOME

0 25
SCALE

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1

1/1/1



SPEC 3.1

NTF BULKHEAD DOME

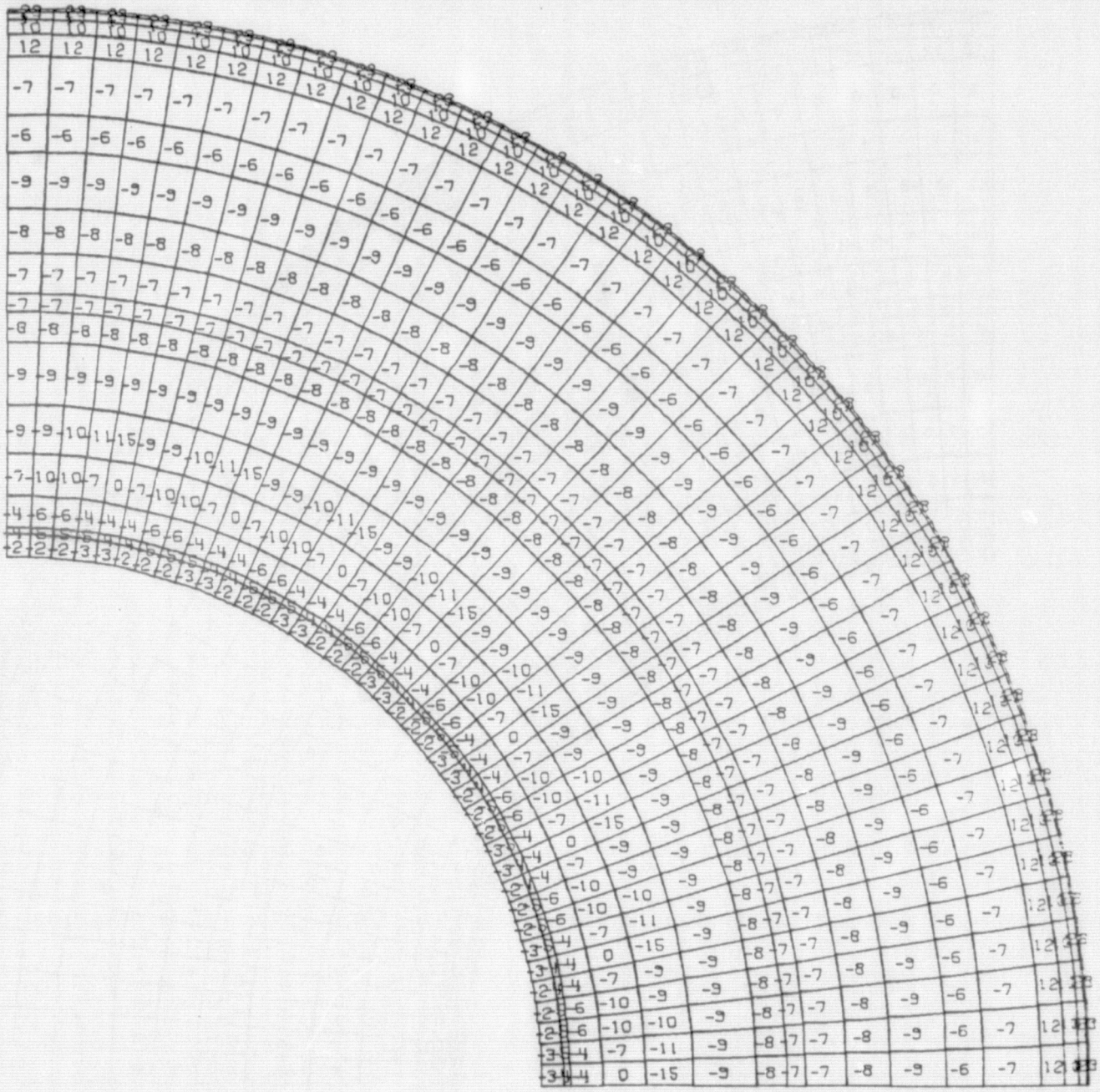
0 2

SCALE

FIG. 119

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2

1/1/1



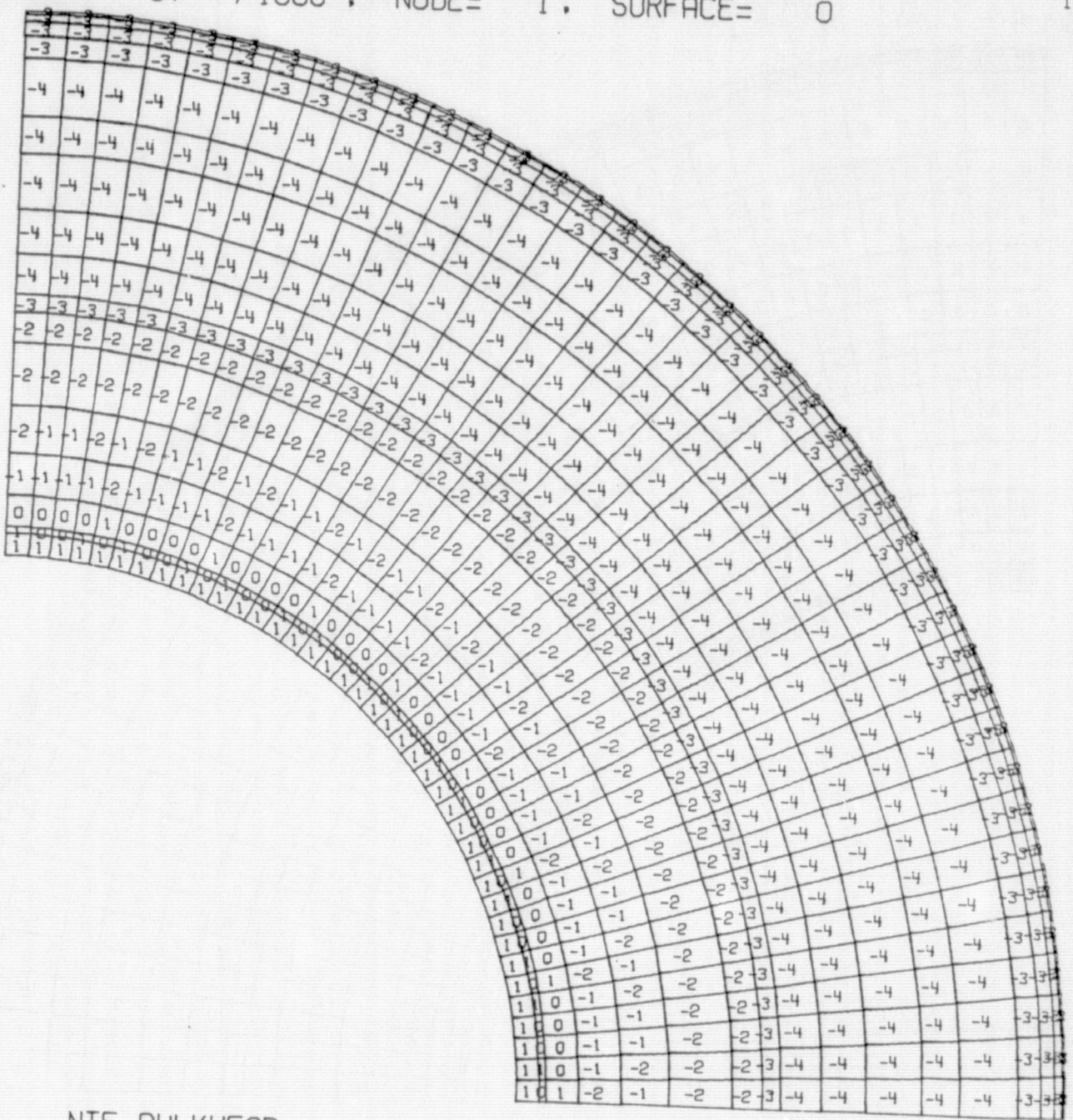
SPEC 3.1

NTF BULKHEAD DOME

0 25
SCALE

Fig. 120

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 0 1/1/1



SPEC 3.1

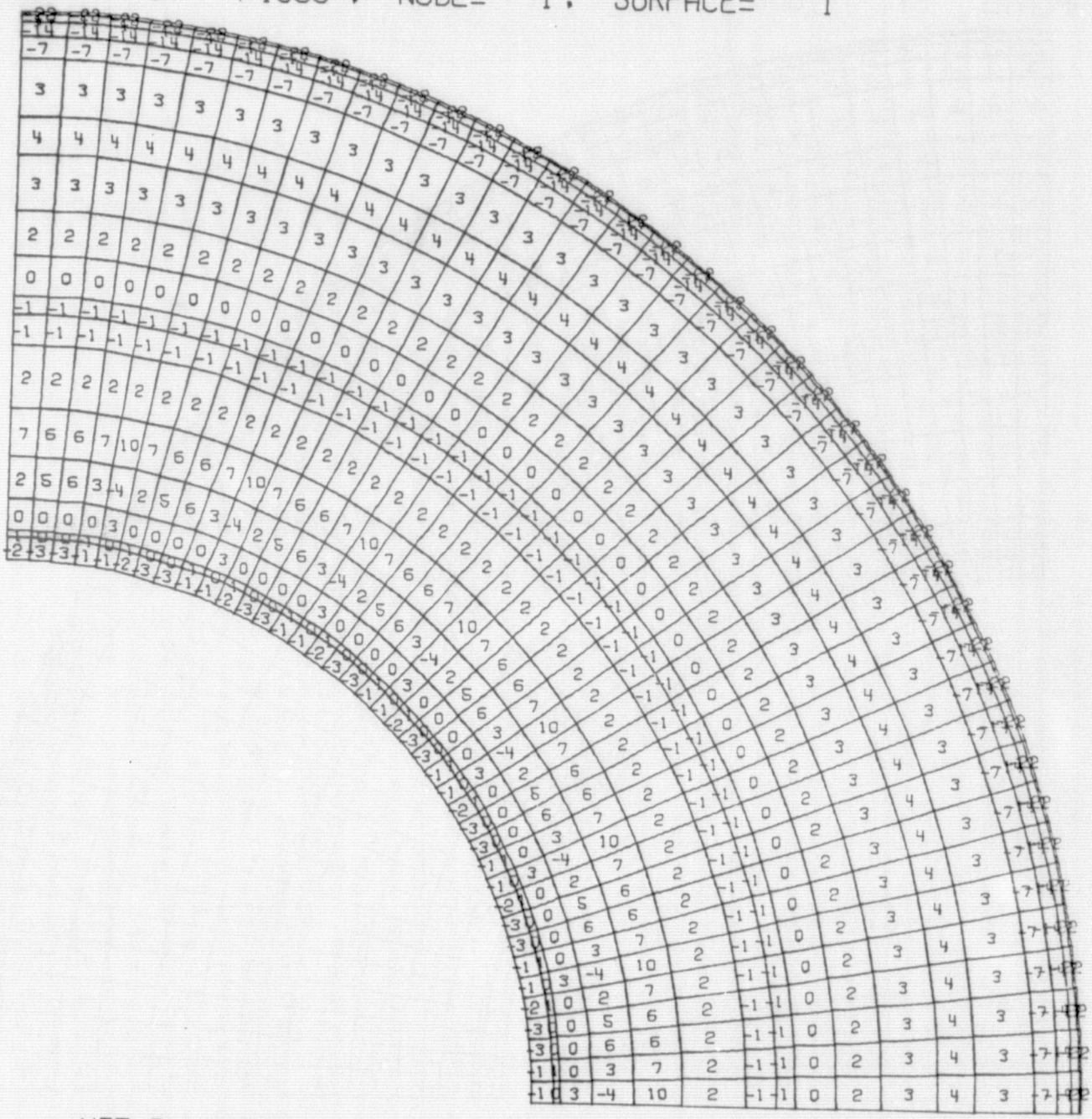
NTF BULKHEAD DOME

0 26
SCALE

FIG. 121

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 1

1/1/1



SPEC 3.1

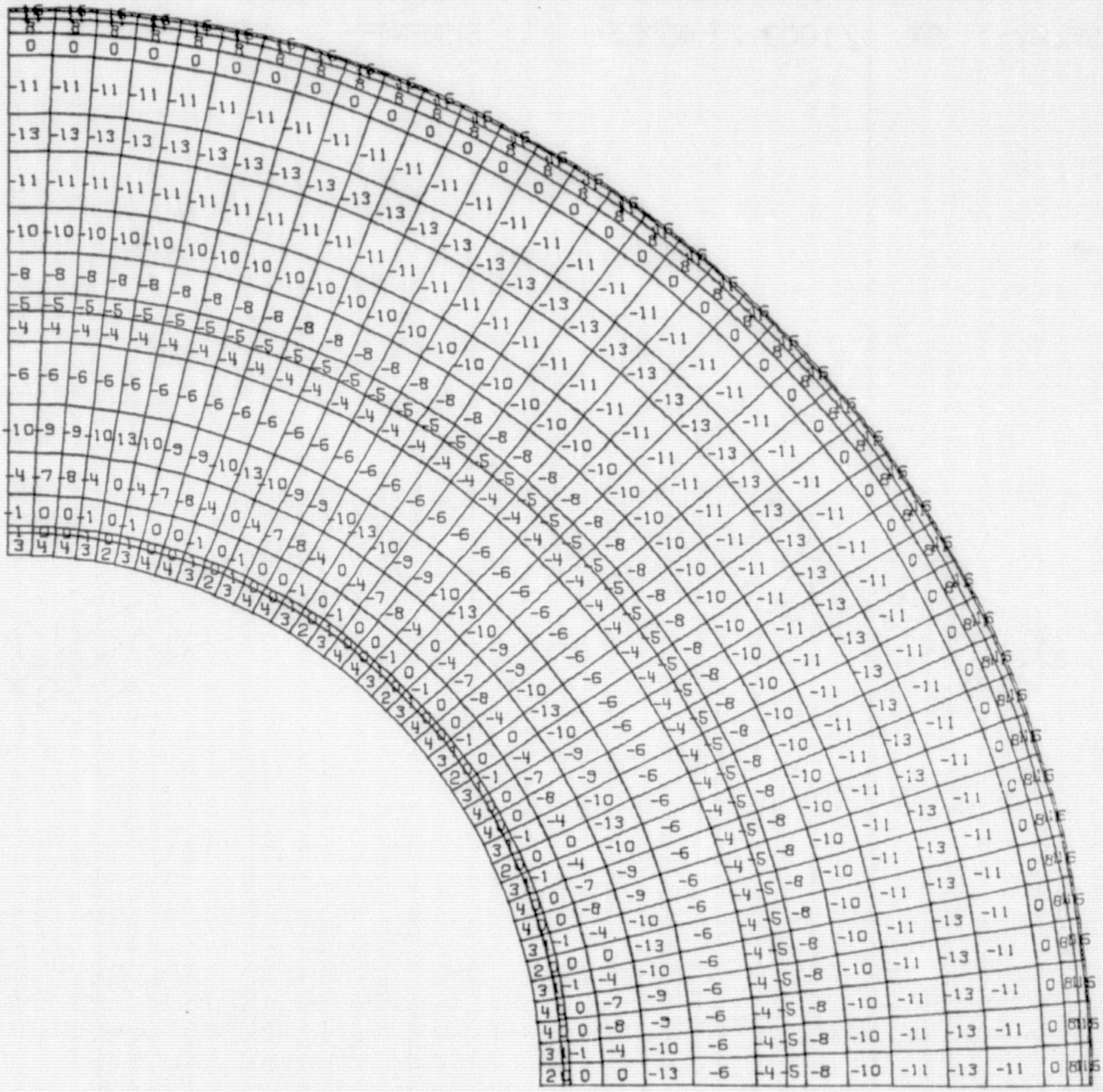
NTF BULKHEAD DOME

0 26

SCALE

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 2

1/1/1



SPEC 3.1

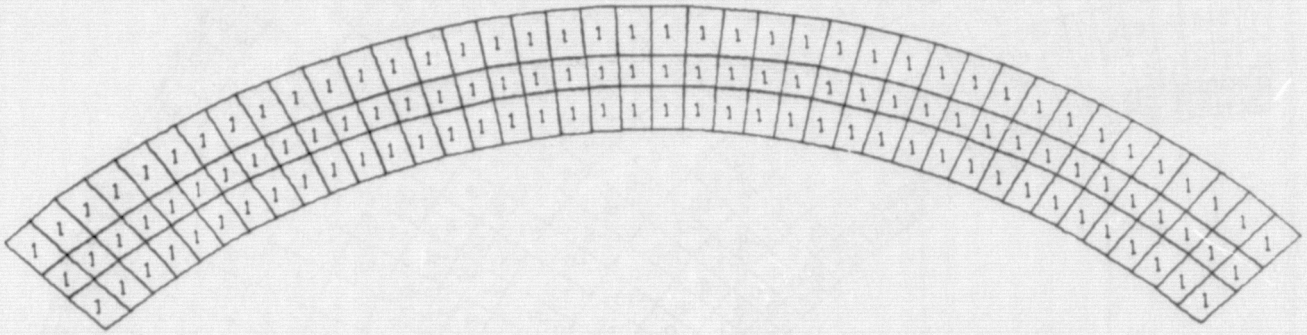
NTF BULKHEAD DOME

0 SCALE 26

FIG. 123

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0

1/1/1



EC .1 NTF BULKHEAD FLANGE SURFACE

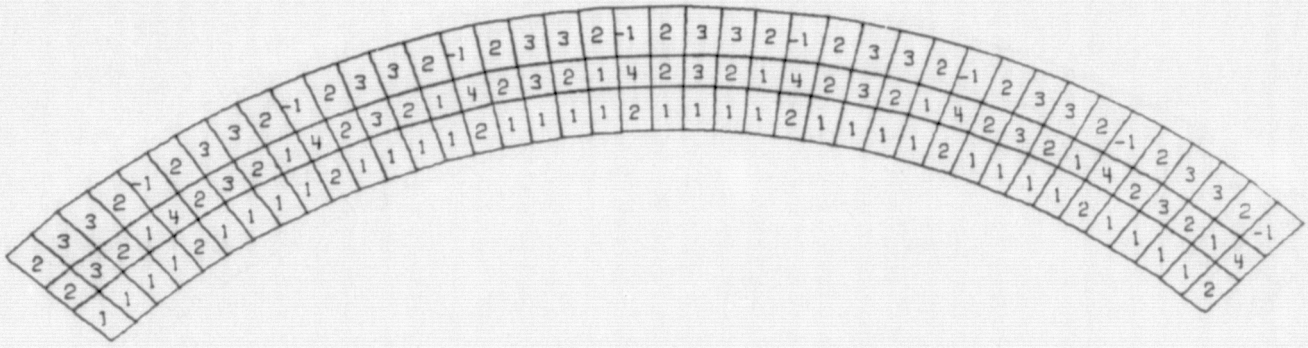
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

0 21 SCALE

)

1/1/1

DISPLAY= SX /1000 . NODE= 1 . SURFACE= 1



SPEC
P 1
)

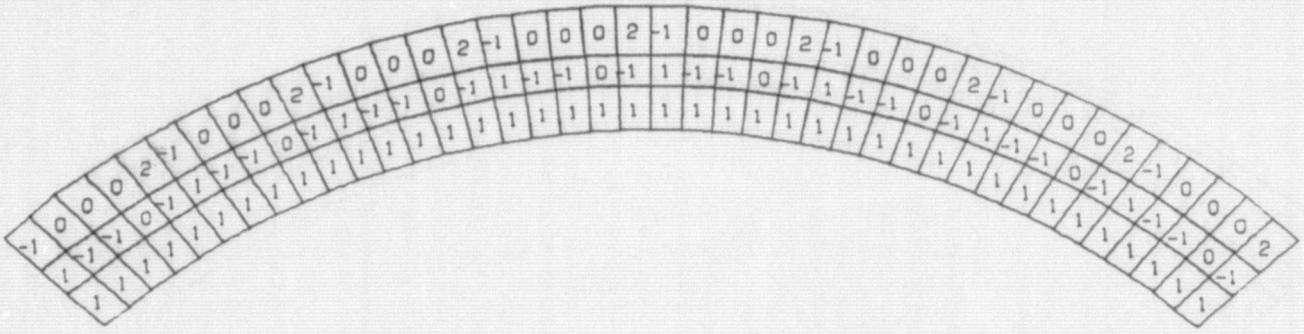
NTF BULKHEAD
FLANGE SURFACE

0 21
SCALE

FIG. 125

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 2

1/1/1



PEC
.1

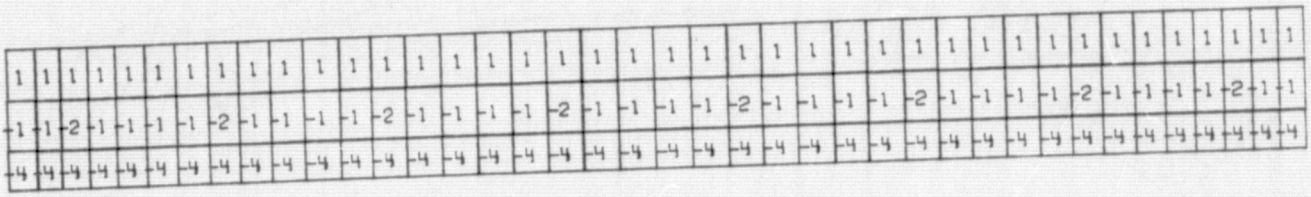
NTF BULKHEAD
FLANGE SURFACE

0 21
SCALE

FIG 12

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 0



SPEC 10.1 NTF BULKHEAD HATCH OPENING

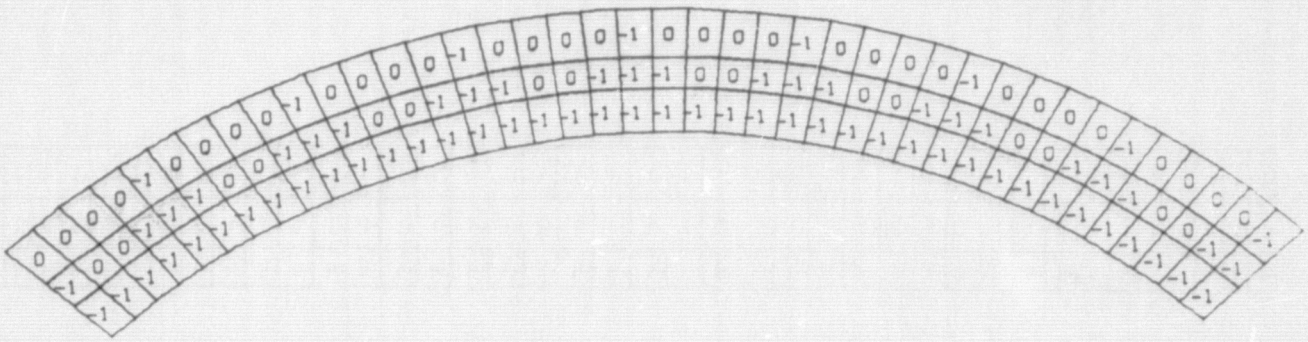
0 SCALE 18

FIG. 127

)

1/1/1

)ISPLAY= SY /1000 . NODE= 1. SURFACE= 0



)

SPEC 2.1 NTF BULKHEAD FLANGE SURFACE

0 2.1
SCALE

)

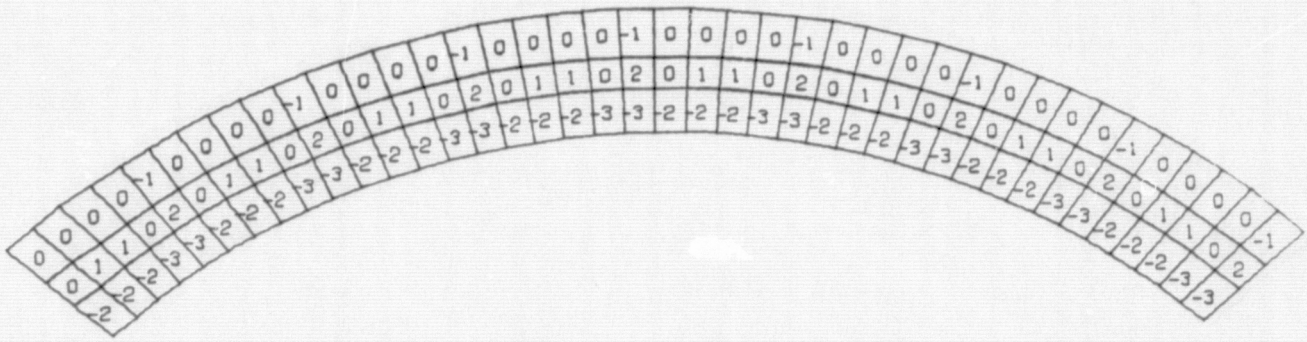
FIG 128

)

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1

)



SPEC 2.1 NTF BULKHEAD FLANGE SURFACE

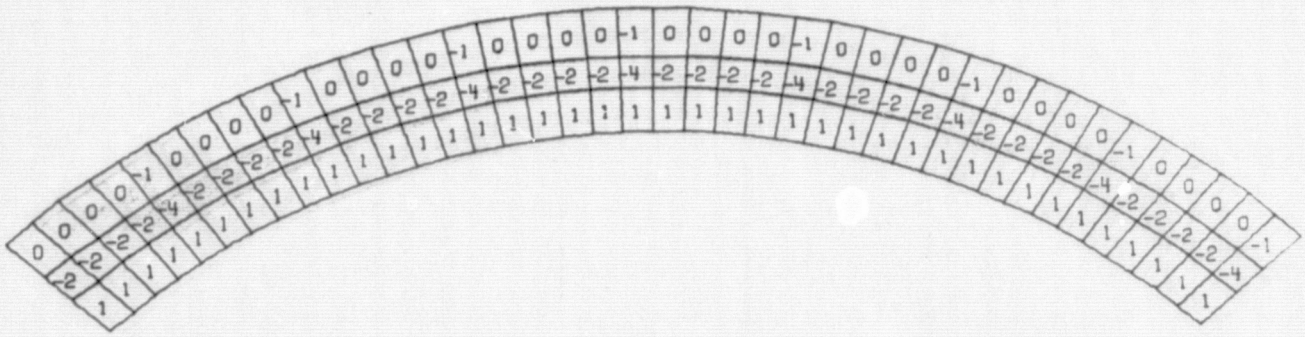
0 21
SCALE

)

FIG. 129

1/1/1

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 2



SPEC 2.1 NTF BULKHEAD FLANGE SURFACE

0 21
SCALE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

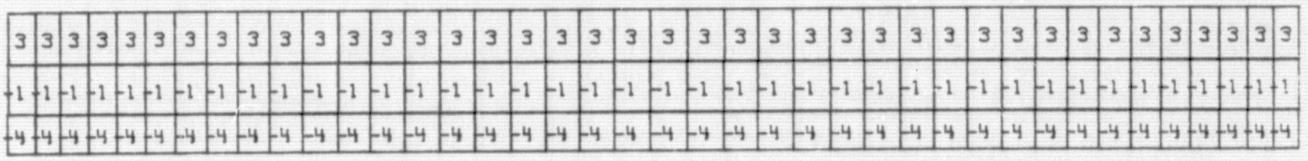
EIL 17A

)

1/1/1

DISPLAY= SX /1000 , NODE= 1 , SURFACE= 1

)



SPEC 10.1 NTF BULKHEAD HATCH OPENING

0 18
SCALE

)

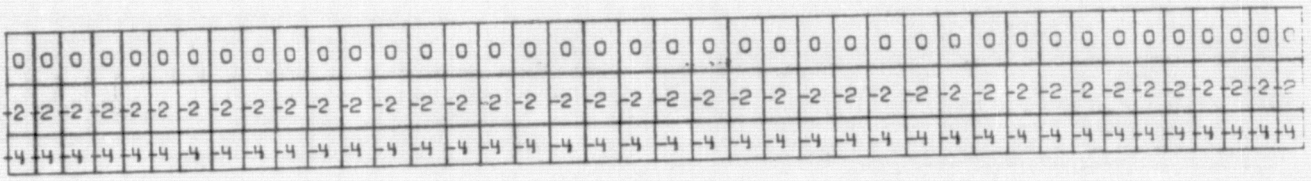
FIG. 134

)

1/1/1

DISPLAY= SX /1000 . NODE= 1 . SURFACE= 2

)



SPEC
10.1

NTF BULKHEAD
HATCH OPENING

0 18
SCALE

)

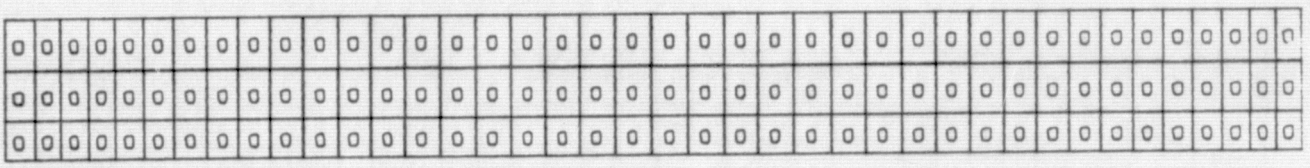
F1/ 17-

)

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0

)



SPEC 10.1 NTF BULKHEAD HATCH OPENING

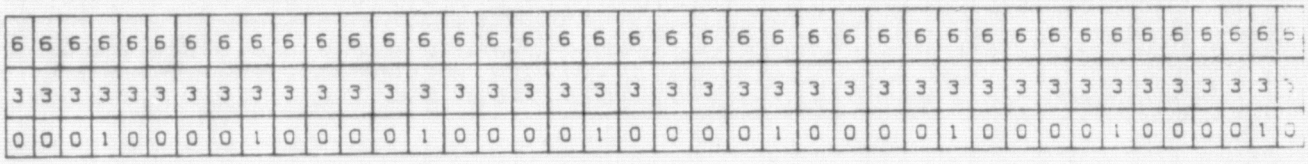
0 18
SCALE

)

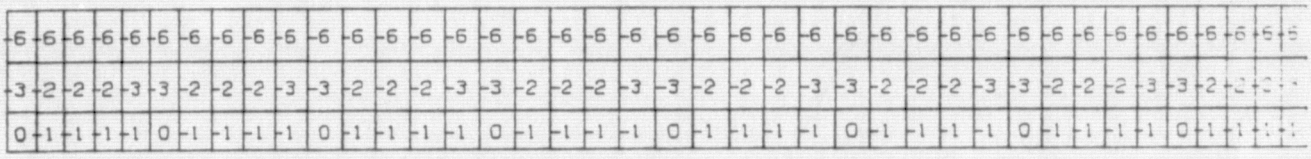
FIG. 133

1/1/1

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1


6 6 6

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 2



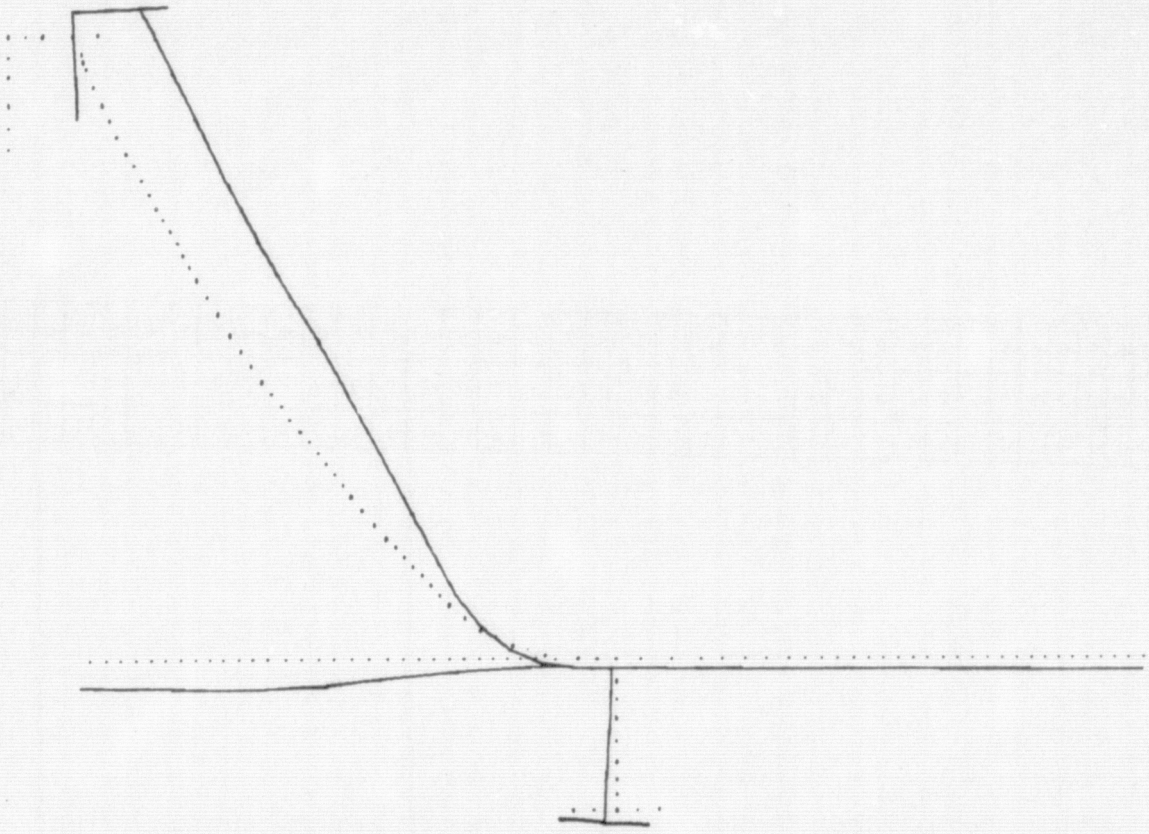
SPEC 10.1

NTF BULKHEAD
HATCH OPENING

0 SCALE 18

FIG. 135

1/1/1

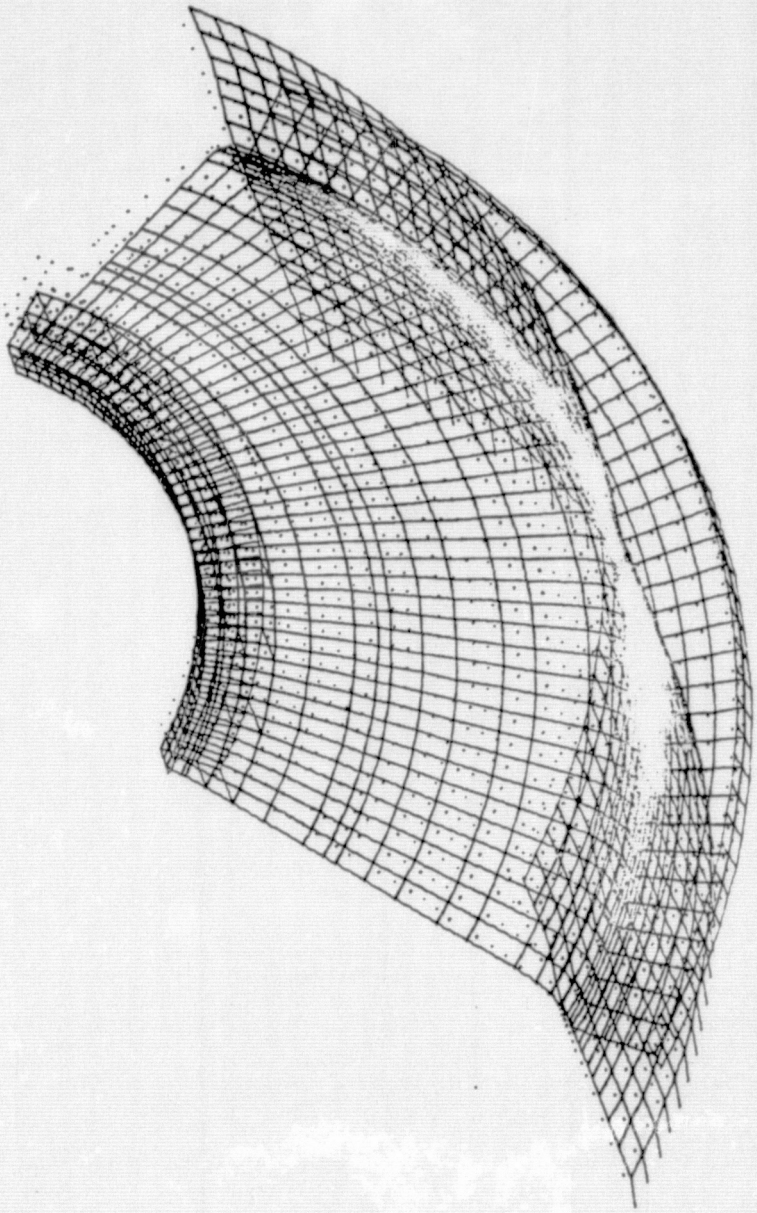


SPEC
12.1

VTF BULKHEAD
CROSS-SECTION VIEW

0 27
SCALE

1/1/1



SPEC 1.1 NTF BULKHEAD

0 SCALE 44

FIG. 137

Case 7

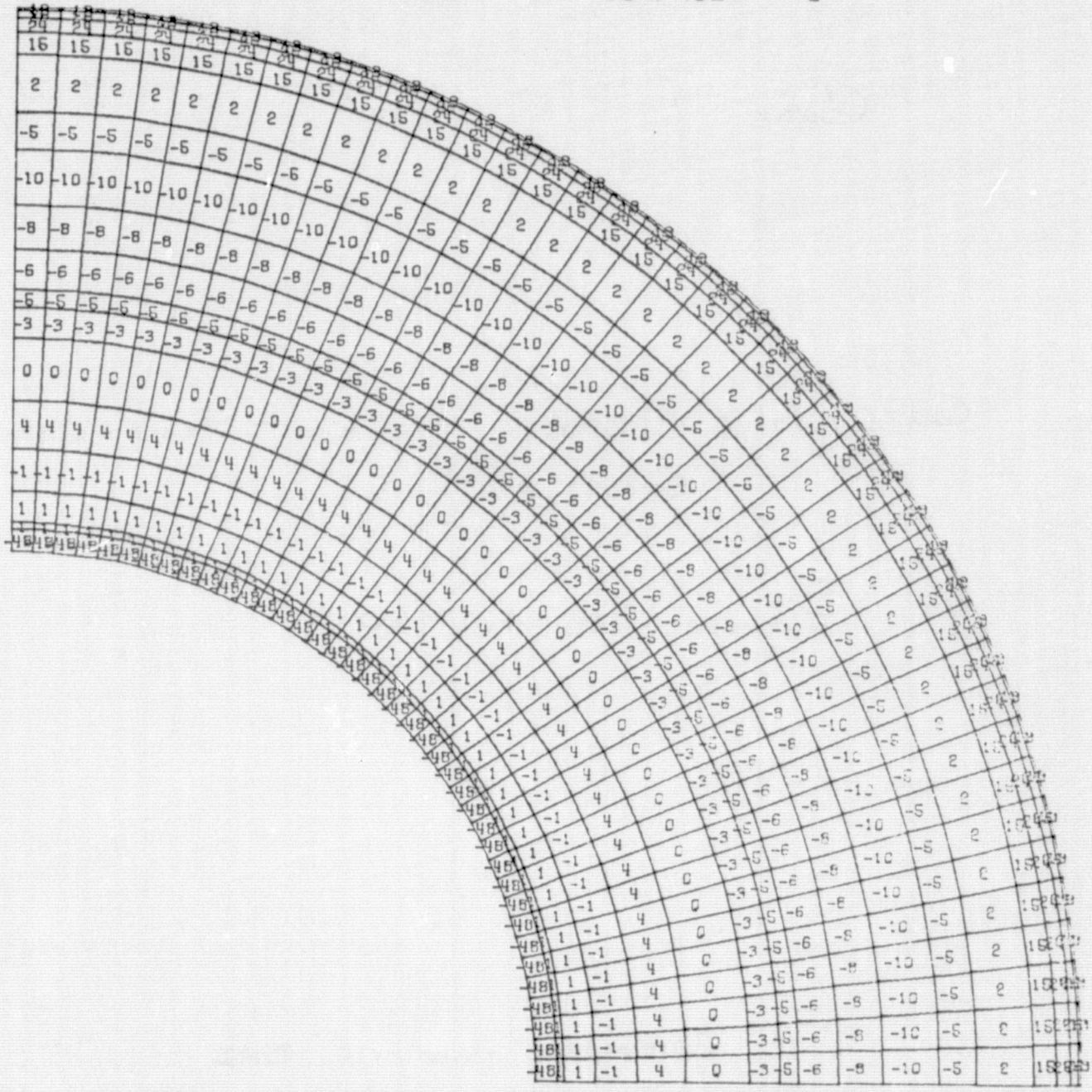
Gate Valve Closed w/ transient temp dist.
stress plots

Figures 138 thru 160

Computer run no. BAI

DISPLAY= SX /1000 . NODE= 1. SURFACE= 0

1/1/1



SPEC 3.1

NTF BULKHEAD DOME

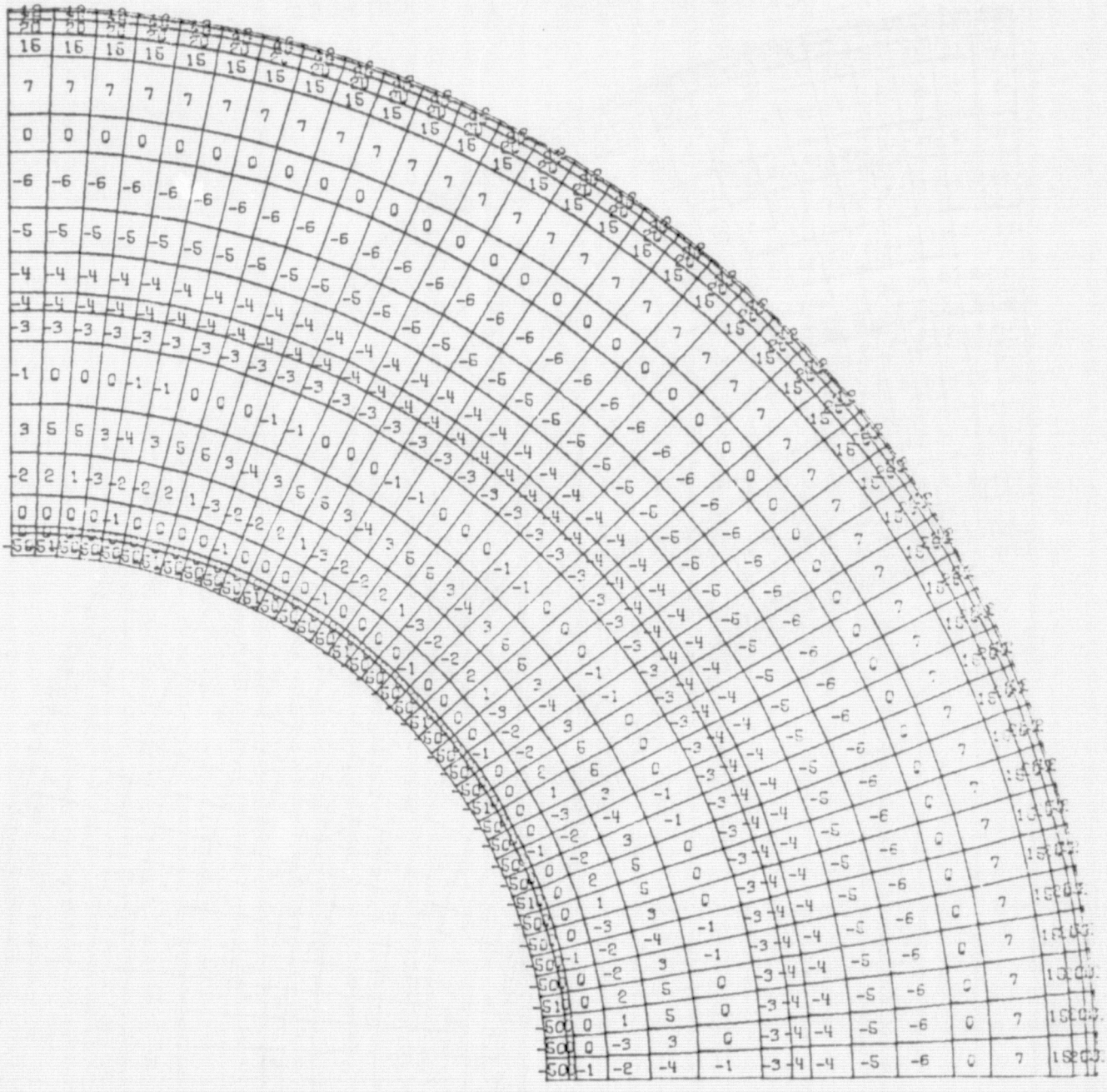
0 26

SCALE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

1/1/1

DISPLAY= SX /1000 . NODE= 1 . SURFACE= 1

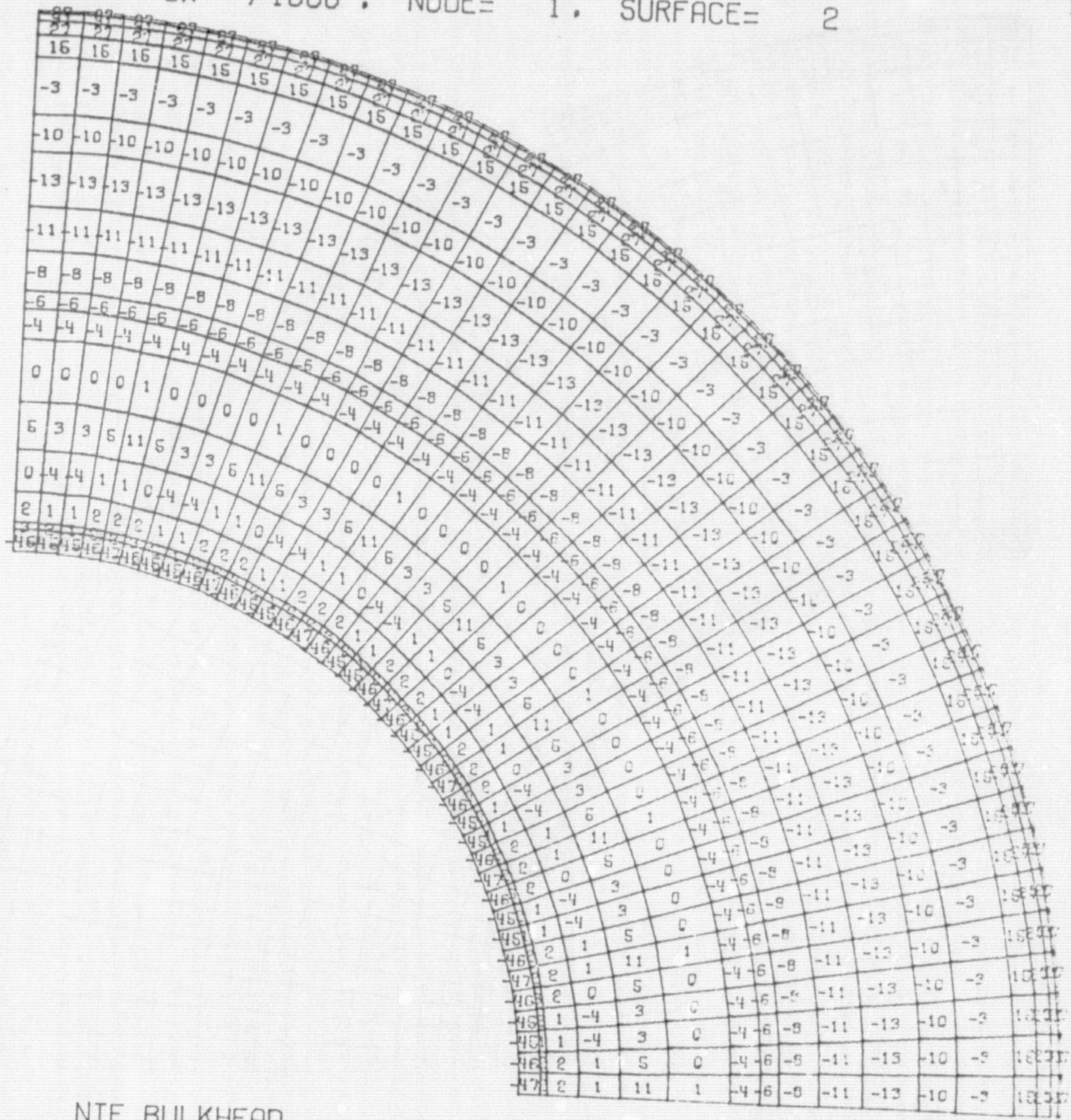


SPEC 3.1 NTF BULKHEAD DOME

0 25
SCALE

FIG. 139

DISPLAY= SX /1000 . NODE= 1 . SURFACE= 2 1/1/1



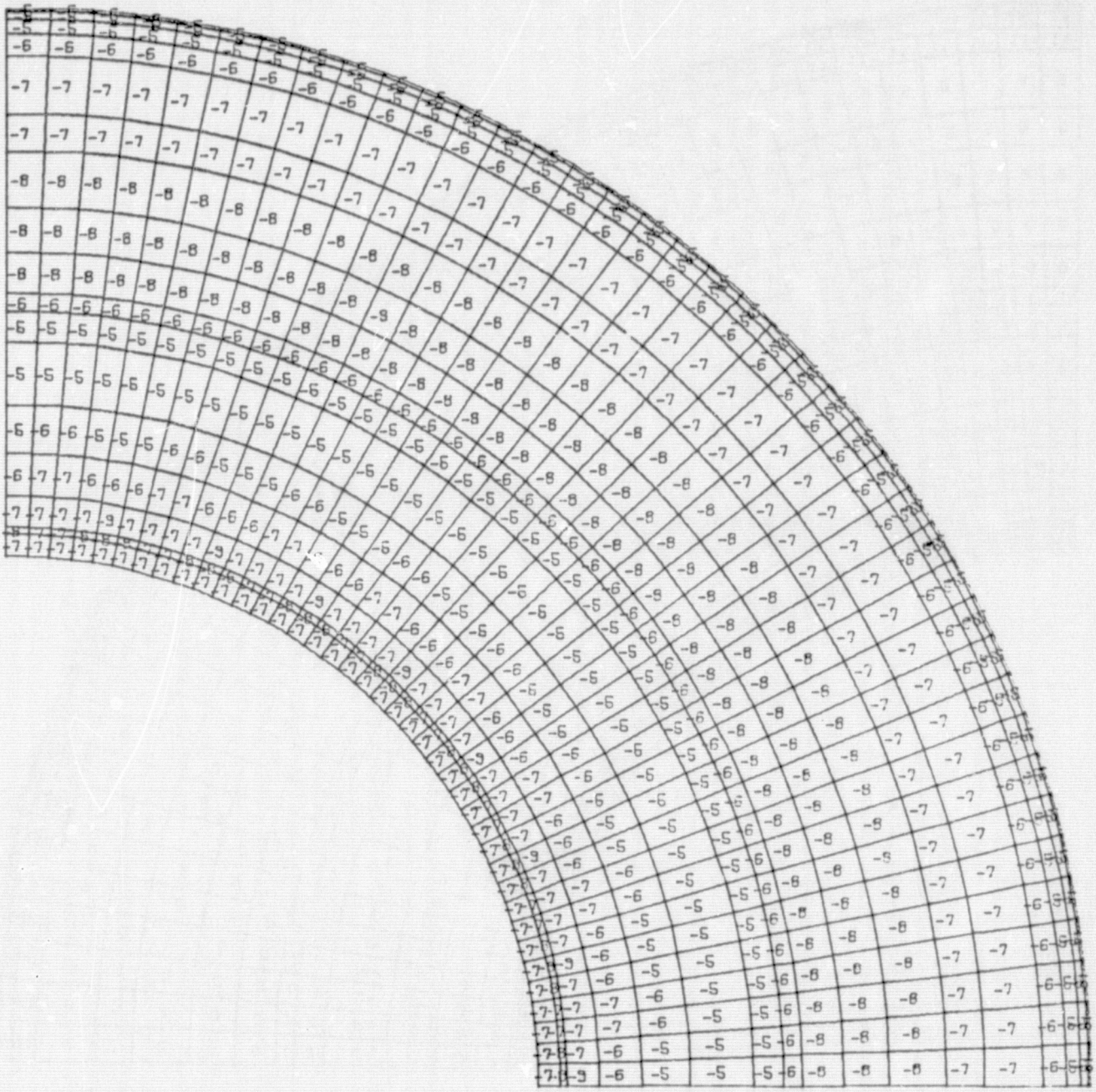
SPEC
3.1

NIF BULKHEAD
DOME

0 SCALE 25

1/1/1

DISPLAY= SY /1000 , NODE= 1, SURFACE= 0



SPEC 3.1

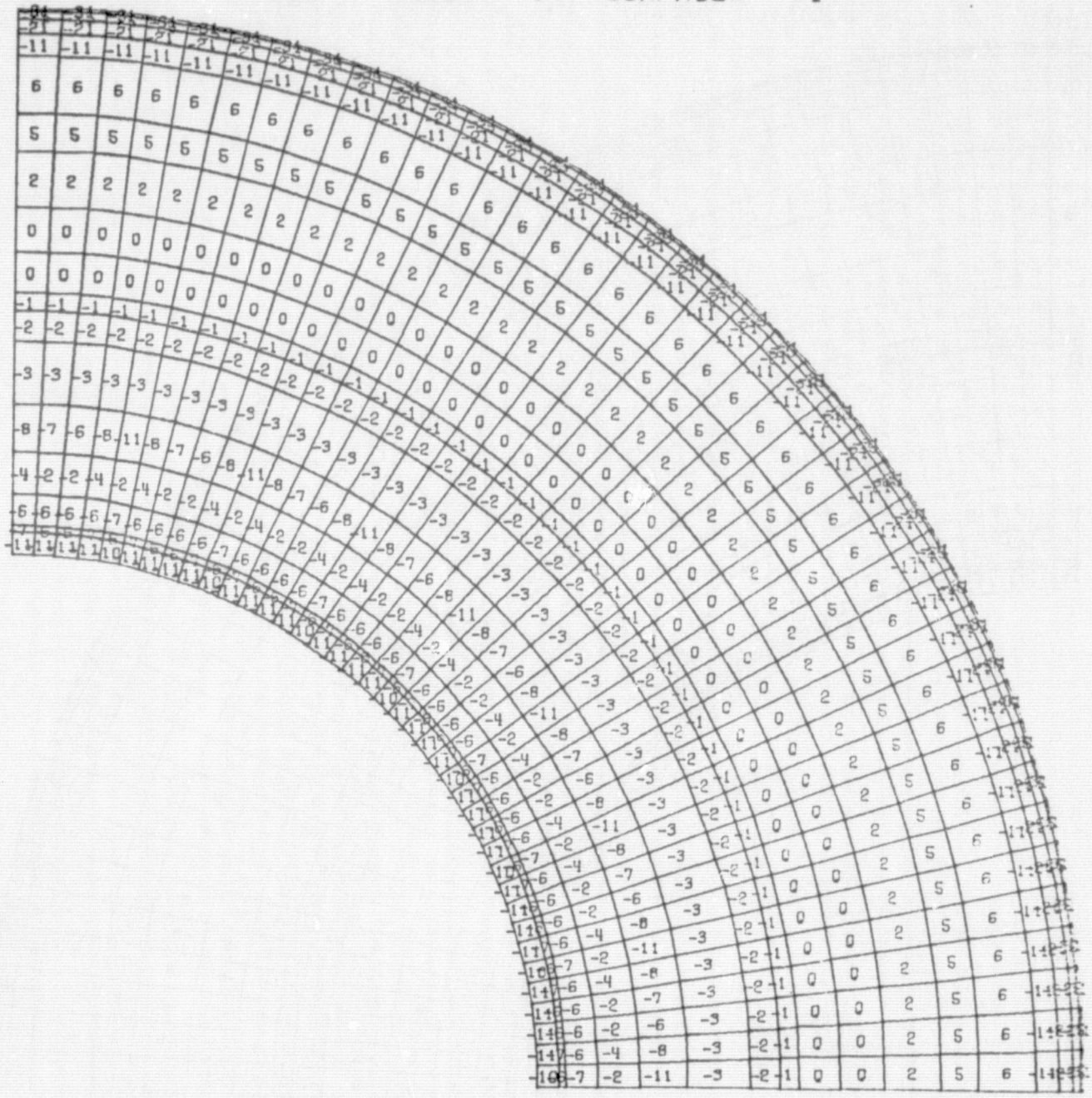
NTF BULKHEAD DOME

0 SCALE 26

FIG. 141

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1

1/1/1



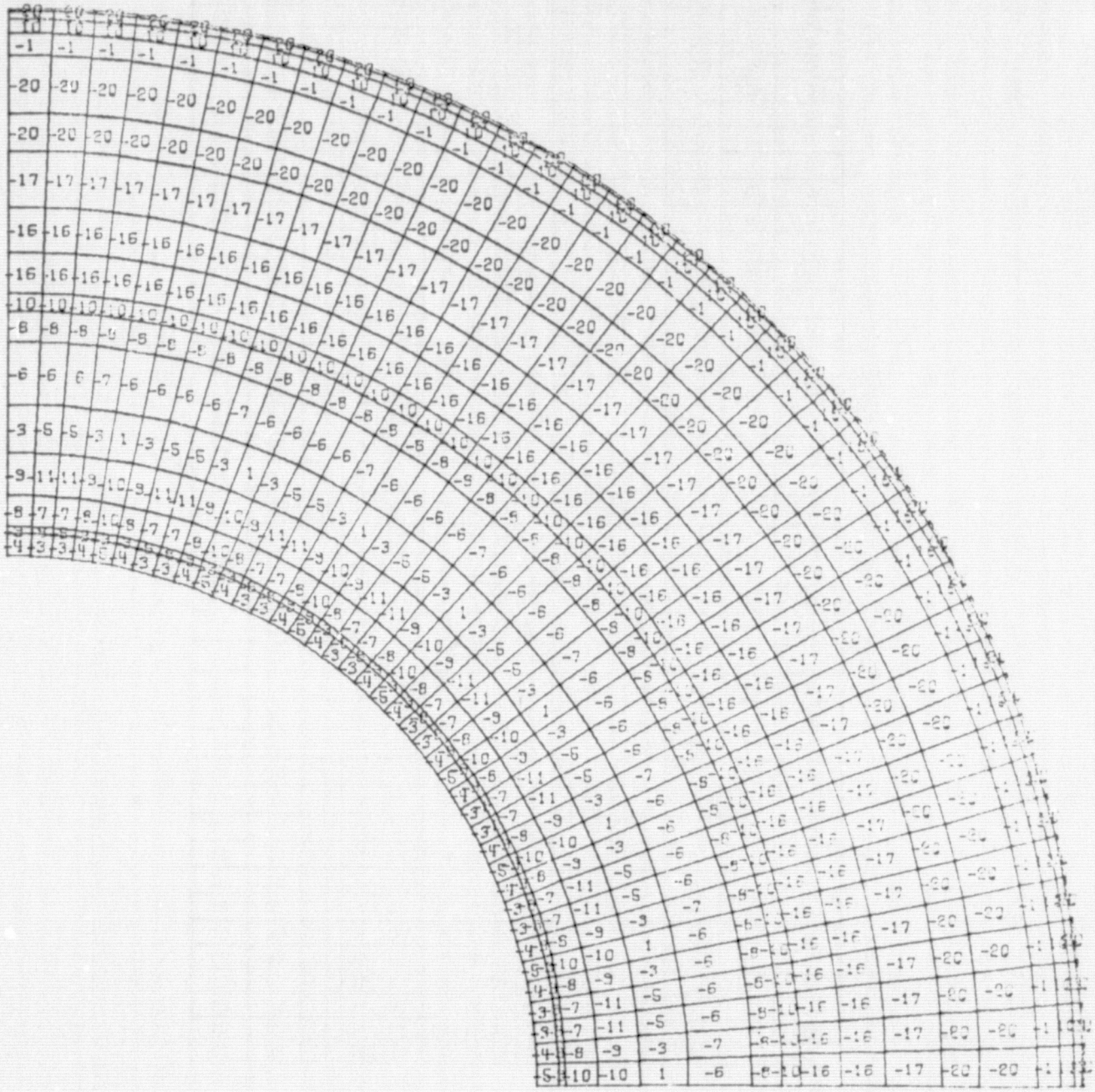
SPEC 3.1

NTF BULKHEAD DOME

0 26
SCALE

1/1/1

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 2



SPEC 3.1

NTF BULKHEAD DOME

0 SCALE 26

FIG. 143

DISPLAY= SX /1000 . NODE= 1. SURFACE= 0

1/1/1

0	0	0	0	1	3	5	7	9	10	12	8	10	15	17	20	21

1/1/1

DISPLAY= SX /1000 . NODE= 1 . SURFACE= 1

0	0	0	0	2	4	5	6	6	6	6	10	6	9	13	18	21	21

DISPLAY= SX /1000 . NODE= 1 . SURFACE= 2

1/1/1

0	0	-1	-1	1	3	5	7	10	13	14	9	11	16	16	19	20

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 0

1/1/1

0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	5	5	5	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	5	5	5	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	5	5	5	10	10	10	10
0	0	0	0	0	0	0	0	0	0	5	5	5	10	10	10	10
0	0	0	0	0	0	0	0	0	0	5	5	5	10	10	10	10
0	0	0	0	0	0	0	0	0	0	5	5	5	10	10	10	10
0	0	0	0	0	0	0	0	0	0	5	5	5	10	10	10	10
0	0	0	0	0	0	0	0	0	0	5	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	5	5	5	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10
0	0	0	0	0	0	0	0	0	0	6	6	6	10	10	10	10

SPEC 5.1 NTF BULKHEAD SHELL

Q SCHEF 36

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

FIG. 149

1/1/1

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 1

0	0	1	2	2	2	0-3[illegible]042	0	2	6	12	13	10

1/1/1

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 2

0	0	-1	-2	-3	-2	0	3	7	9	13	12	10	8	14	8	7	10

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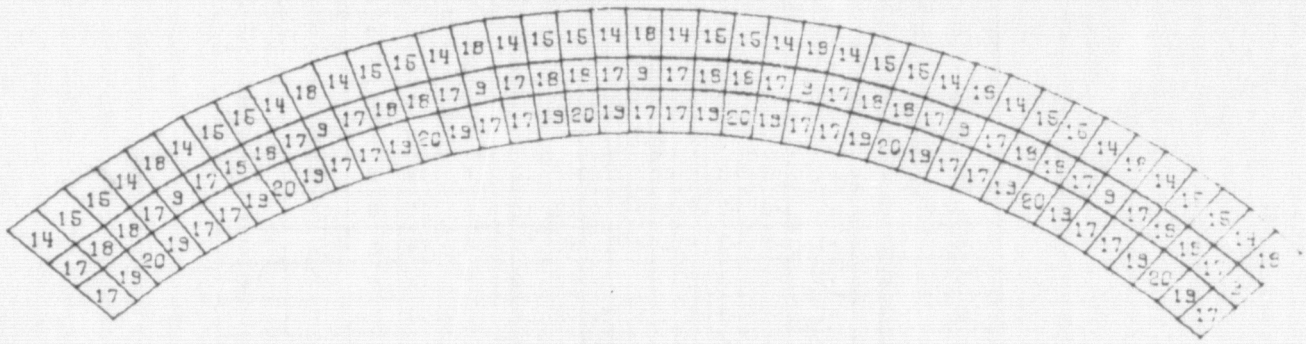
1/1/1



SPEC 2.1 NTF BULKHEAD FLANGE SURFACE

Q SCALE: 21

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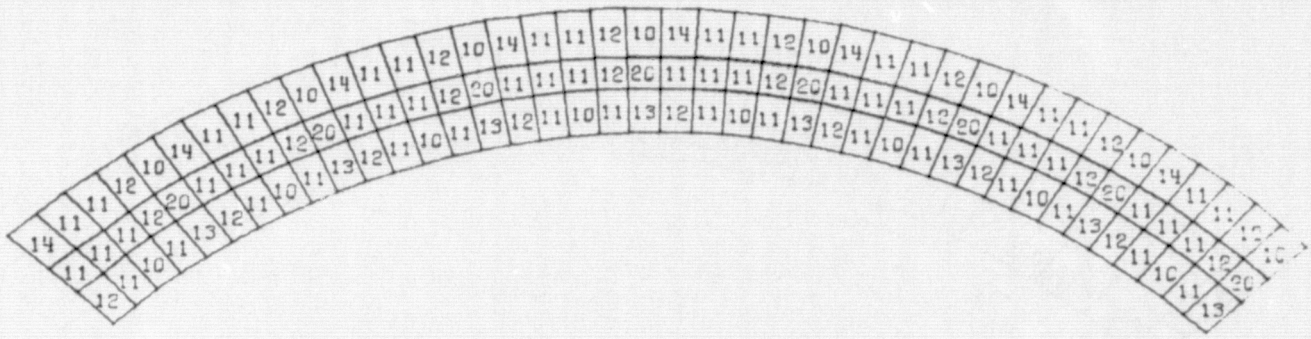
ORIGINAL PAGE IS POOR

FIG 15D

DISPLAY= SX /1000 . NODE= 1 . SURFACE= 2

1/1/1



SPEC 2.1

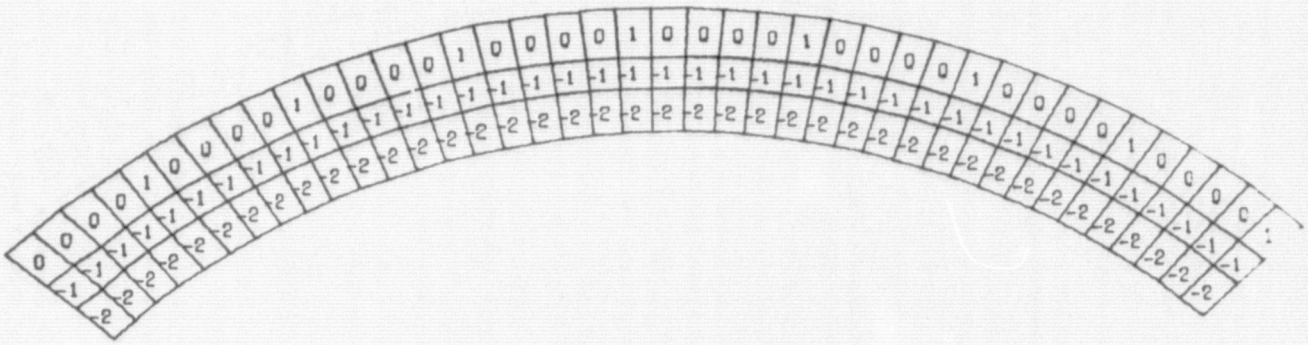
NTF BULKHEAD FLANGE SURFACE

0 SCALE 21

FIG. 15

1/1/1

DISPLAY= SY /1000 . NODE= 1. SURFACE= 0



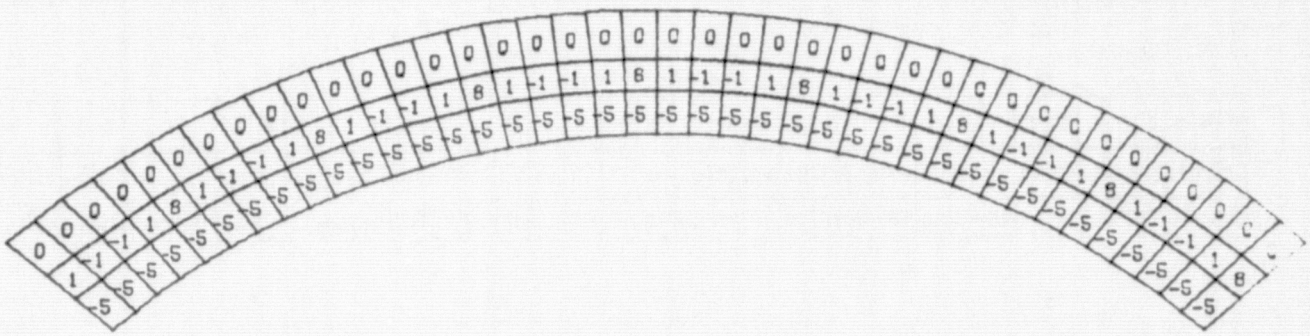
SPEC 2.1

NTF BULKHEAD FLANGE SURFACE

0 21
SCALE

DISPLAY= SY /1000 . NODE= 1 . SURFACE= 2

1/1/1



SPEC 2.1

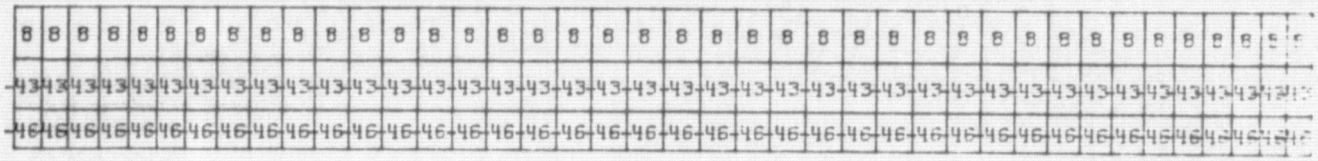
NTF BULKHEAD FLANGE SURFACE

0 21
SCALE

FIG. 153

DISPLAY= SX /1000 . NODE= 1 . SURFACE= 0

1/1/1

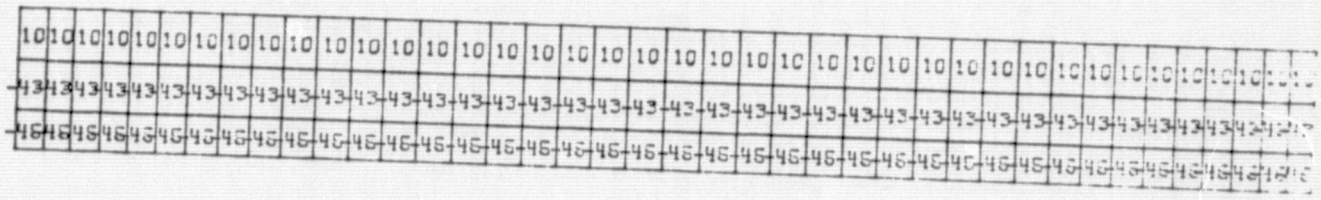


SPEC 10.1

NTF BULKHEAD HATCH OPENING

0 18
SCALE

DISPLAY= SX /1000 . NODE= 1. SURFACE= 1 1/1/1



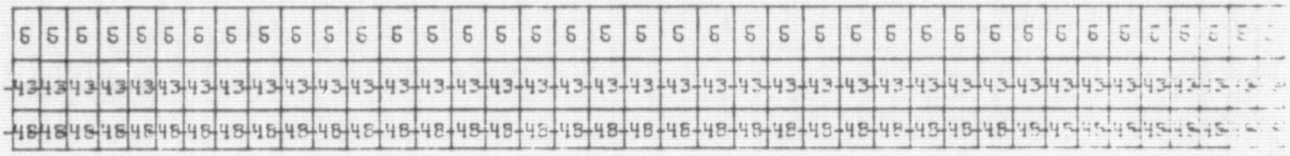
SPEC
10.1

NTF BULKHEAD
HATCH OPENING

0 18
SCALE

FIG.155

DISPLAY= SX /1000 . NODE= 1 . SURFACE= 2

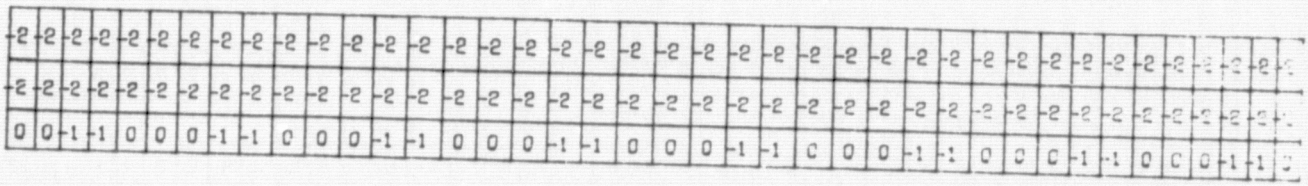


SPEC 10.1

NTF BULKHEAD
HATCH OPENING

Fig. 10a

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 0 1/1/1



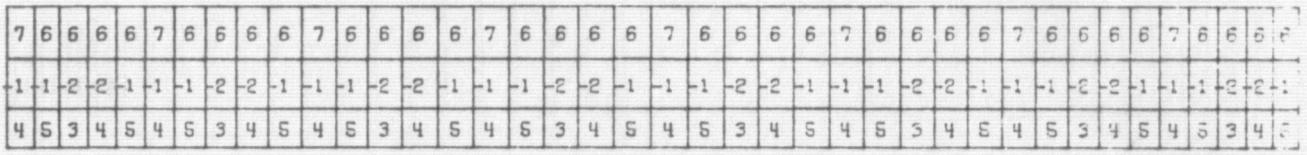
SPEC 10.1 NTF BULKHEAD HATCH OPENING

0 18
SCALE

FIG 157

DISPLAY= SY /1000 , NODE= 1 , SURFACE= 1

1/1/1



SPEC 10.1 NTF BULKHEAD HATCH OPENING

0 18 SCALE

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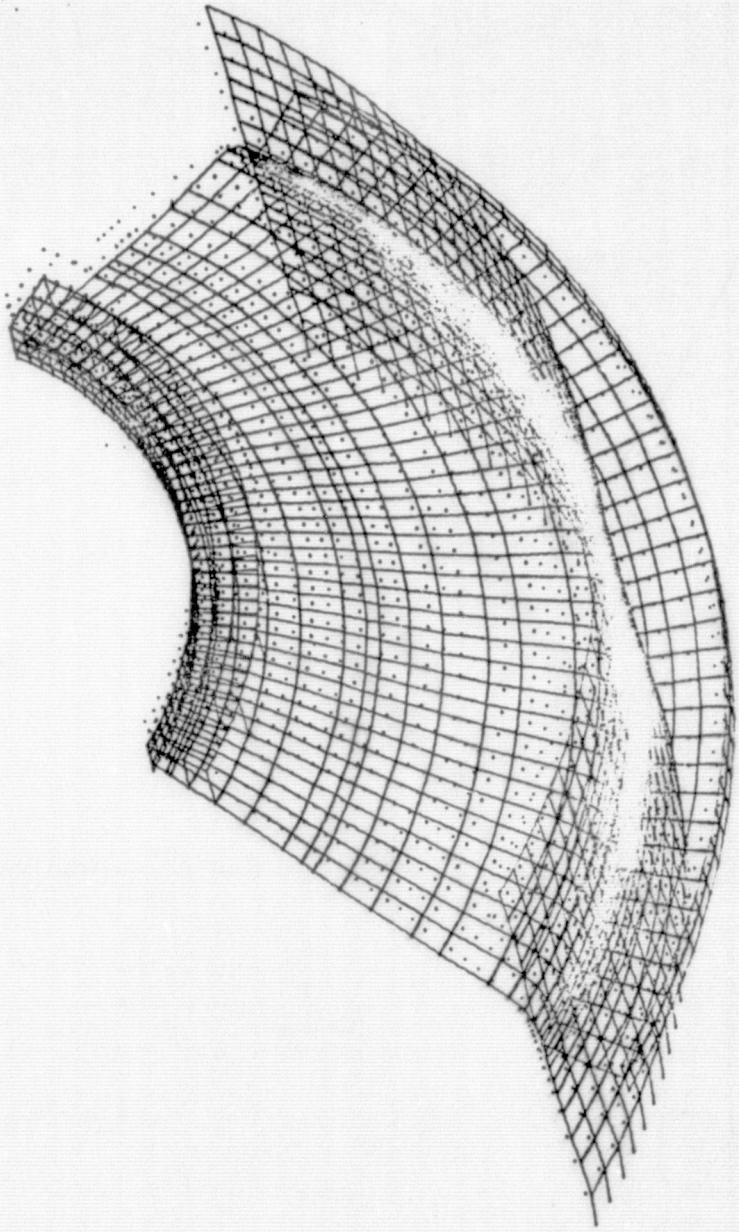
1/1/1



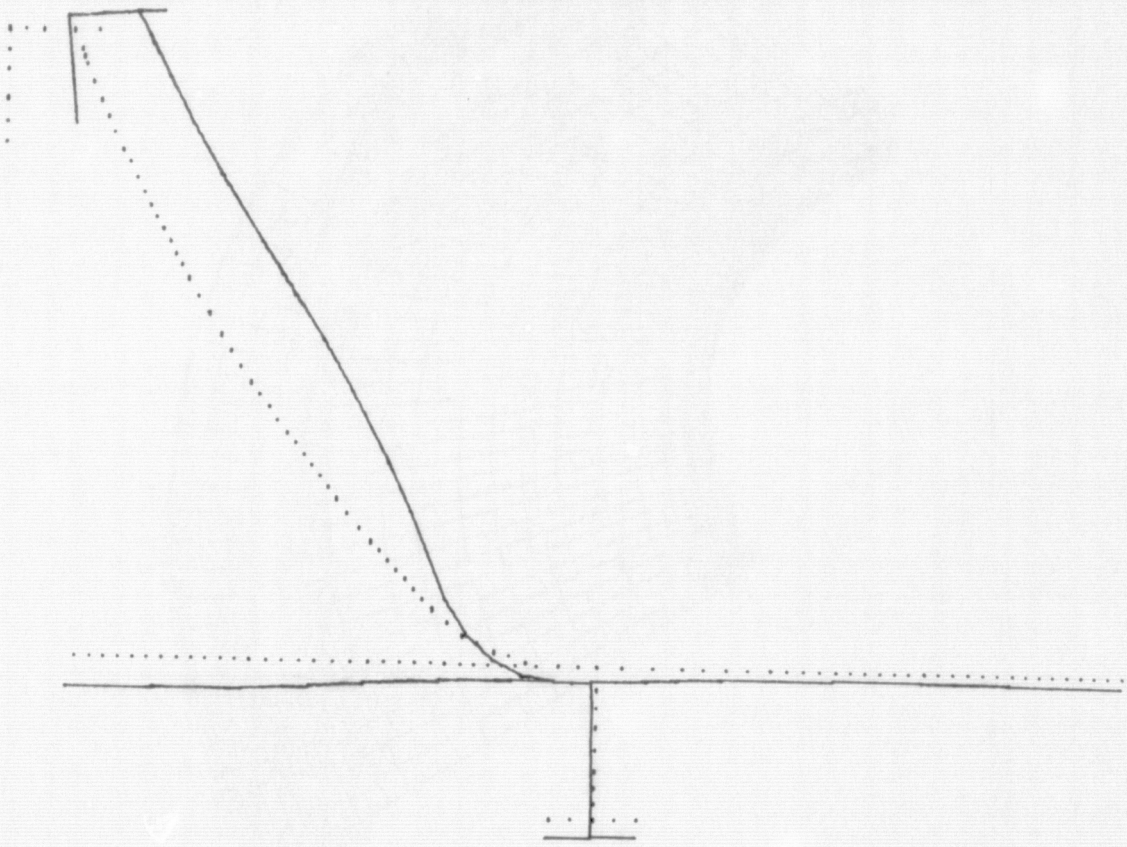
SPEC 1.1 NTF BULKHEAD

0 44
SCALE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

F16 /59

1/1/1



SPEC
12.1

NTF BULKHEAD
CROSS-SECTION VIEW

0 SCALE 27

BY _____ DATE _____ SUBJECT _____ SHEET NO. 86 OF _____

CHKD. BY _____ DATE _____ JOB NO. _____

S4 & S5 Ring Analysis

Asymmetric Ring Loads

Mat'l 9% Ni

NTF 54 & 55 RING ANALYSIS

(99 NI)

I DESCRIPTION ——— 88

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A. GEOMETRY ——— 91

B. LOADS ——— 96

VI STRESS SUMMARY (OPERATING) — 97

V COMPUTER MODEL (Hydro) — 98

VI Hydro STATIC PRESSURE STRESSES — 99

VII STRESS SUMMARY (Hydro) ——— 100

VIII STRESS EVALUATION ——— 101

BY_____ DATE_____ SUBJECT_____ SHEET NO. 83 OF_____

CHKD. BY_____ DATE_____ JOB NO._____

DESCRIPTION

STRESSES IN SUBJECT RING HAVE BEEN CALCULATED BASED ON EXTERNAL LOADS SUPPLIED BY A/E. THESE STRESSES HAVE BEEN SUPERIMPOSED ON PRESSURE STRESSES FROM A FINITE ELEMENT MODEL. THE RESULTING COMBINED STRESSES FOR BOTH HYDRO AND NORMAL OPPERATIONS ARE CONSIDERED, AND THE STRESS EVALUATION FOLLOWS. THE RING AS PRESENTLY DESIGNED MEETS BOTH THE STRESS CRITERIA AND AISC CODE.

COMPOTER CODES

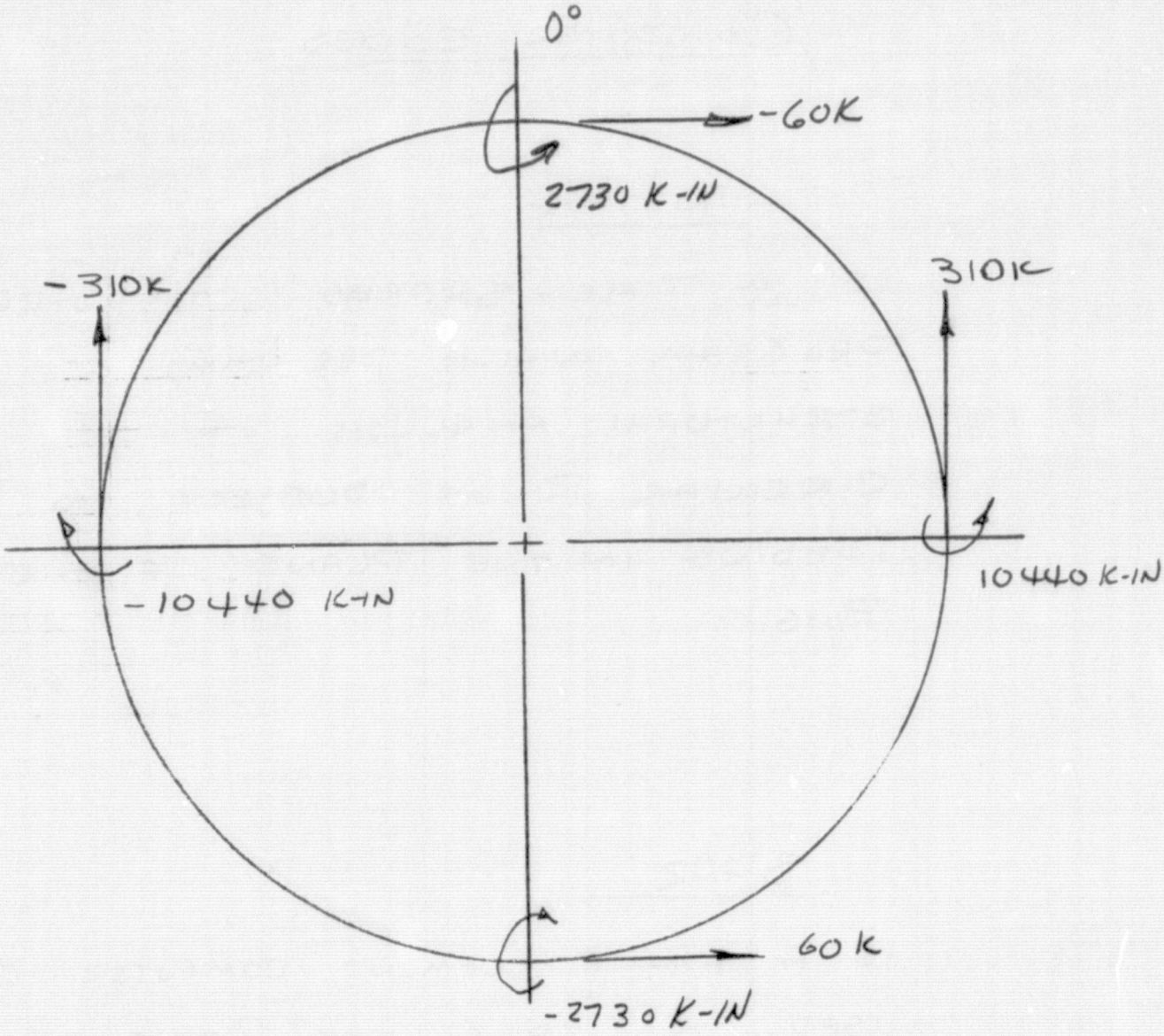
IN RING

IS a TIME-SHARED COMPUTER PROGRAM WHICH PERFORMS a STRUCTURAL ANALYSIS of CIRCULAR RINGS SUBJECT TO LOADING IN THE PLANE OF THE RING.

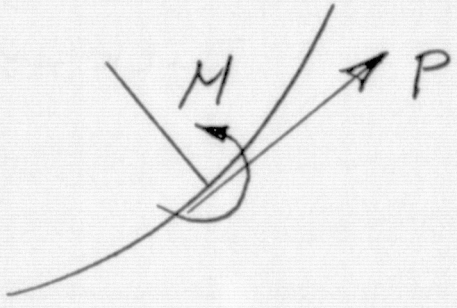
SPAR

IS A FINITE ELEMENT COMPUTER CODE USED TO CALCULATE PRESSURE STRESSES FROM a full PRESSURE (P= 119 PSIG) CYCLE ON A BULK HEAD COMPUTER MODEL.

COMPUTER MODEL FOR OPERATING CASE



SIGN CONVENTION

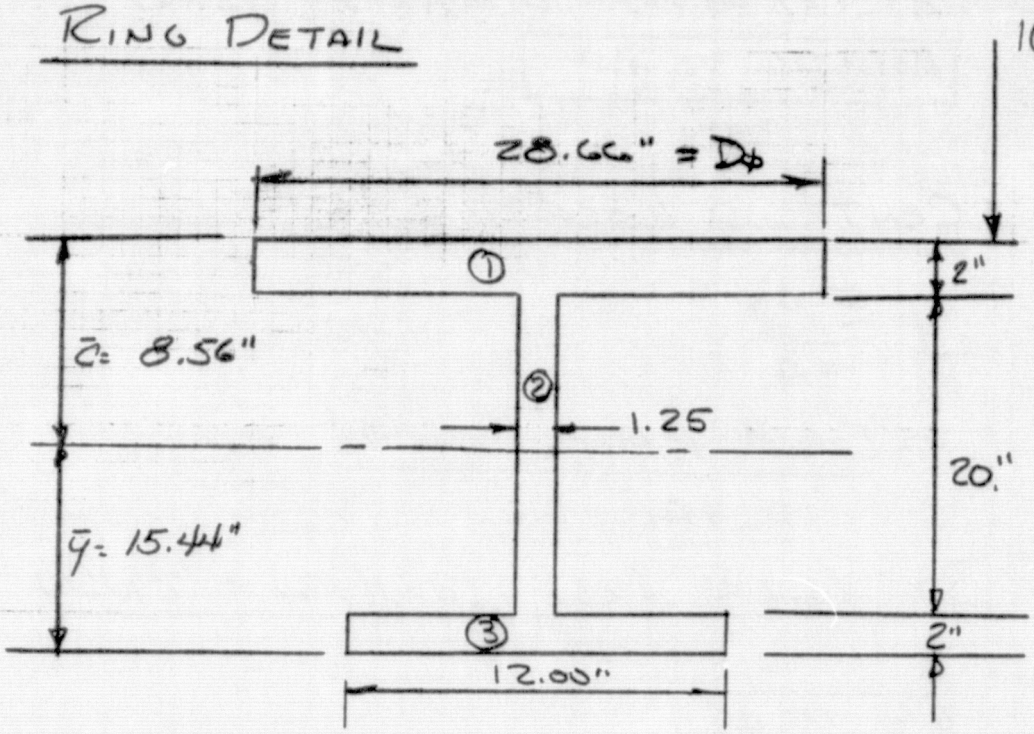


BY _____ DATE _____ SUBJECT _____ SHEET NO. 91 OF _____

CHKD. BY _____ DATE _____ JOB NO. _____

RING DESIGN FOR 9% NI STEEL

RING DETAIL



D_o = 339.5"

t = 2.0"

$1.1\sqrt{D_o t} = 1.1[339.5 \times 2]^{1/2} = 28.66"$

CROSS SECTIONAL AREA

$$A = A_1 + A_2 + A_3$$

$$A = (2)(28.66) + (1.25)(20) + (12 \times 2)$$

$$\boxed{A = 106.32 \text{ IN}^2}$$

CENTROID LOCATION

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

$$\bar{y} = \frac{A_1 d_1 + A_2 d_2 + A_3 d_3}{A_1 + A_2 + A_3}$$

$$\bar{y} = \frac{(57.32)(23) + (25)(12) + (24)(1)}{106.32}$$

$$\boxed{\bar{y} = 15.44 \text{ IN}}$$

$$\bar{c} = 24 - 15.44 = 8.56$$

$$\boxed{\bar{c} = 8.56 \text{ IN}}$$

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

MOMENT OF INERTIA

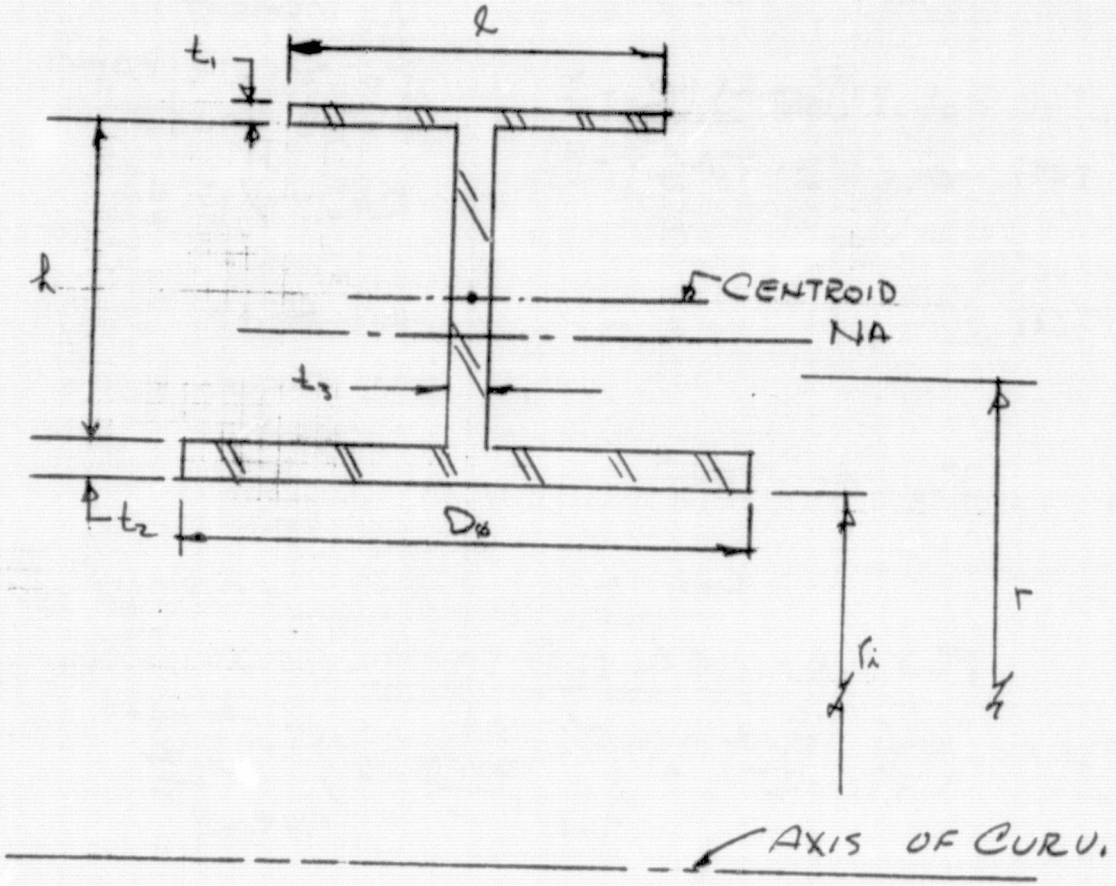
$$I = \Sigma (I_i + A_i d_i^2)$$

$$I = \tfrac{1}{12}(28.66)(2)^3 + \tfrac{1}{12}(1.25)(20)^3 + \tfrac{1}{12}(12)(2)^3 + (57.32)(7.56)^2 + (25)(3.44)^2 + (24)(14.44)^2$$

$$I = 19.11 + 833.33 + 8 + 3276.04 + 295.84 + 5004.33 = 9428.65$$

$$\boxed{I = \quad \text{IN}^4}$$

BENDING OF CURVED BEAMS



BY _____ DATE _____ SUBJECT _____ SHEET NO. 94 OF _____

CHKD. BY _____ DATE _____ JOB NO. _____

BENDING STRESS FOR CURVE BEAMS

BENDING STRESS FOR CURVED BEAMS IS GIVEN BY:

$$\sigma_0 = \frac{M(R-r)}{rA(\bar{r}-R)}$$

M = MOMENT

r = STRESS POINT

$\bar{r}$ = CENTROID

$$R = A \Big/ \int_A \frac{dA}{r}$$

A = AREA

R, for "TEE"

$$R = \frac{t_1 l + h t_3 + D_\phi t_2}{\int_{r_i}^{r_i+t_2} \frac{D_\phi\, dr}{r} + \int_{r_i+t_2}^{r_i+t_2+h} \frac{t_3\, dr}{r} + \int_{r_i+t_2+h}^{r_i+t_2+h+t_1} \frac{l\, dr}{r}}$$

$$R = \frac{t_1 l + h t_3 + D_\phi t_2}{D_\phi \ln\left(\frac{r_i+t_2}{r_i}\right) + t_3 \ln\left(\frac{r_i+t_2+h}{r_i+t_2}\right) + l \ln\left(\frac{r_i+t_2+h+t_1}{r_i+t_2+h}\right)}$$

GEOMETRICAL & MATERIAL PROPERTIES

D_o = 28.66 IN
t_1 = 2.0 IN
t_2 = 2.0 IN
t_3 = 1.25 IN
ℓ = 12.0 IN
r_i = 167.75 IN
F = 176.31 IN
R = 20"

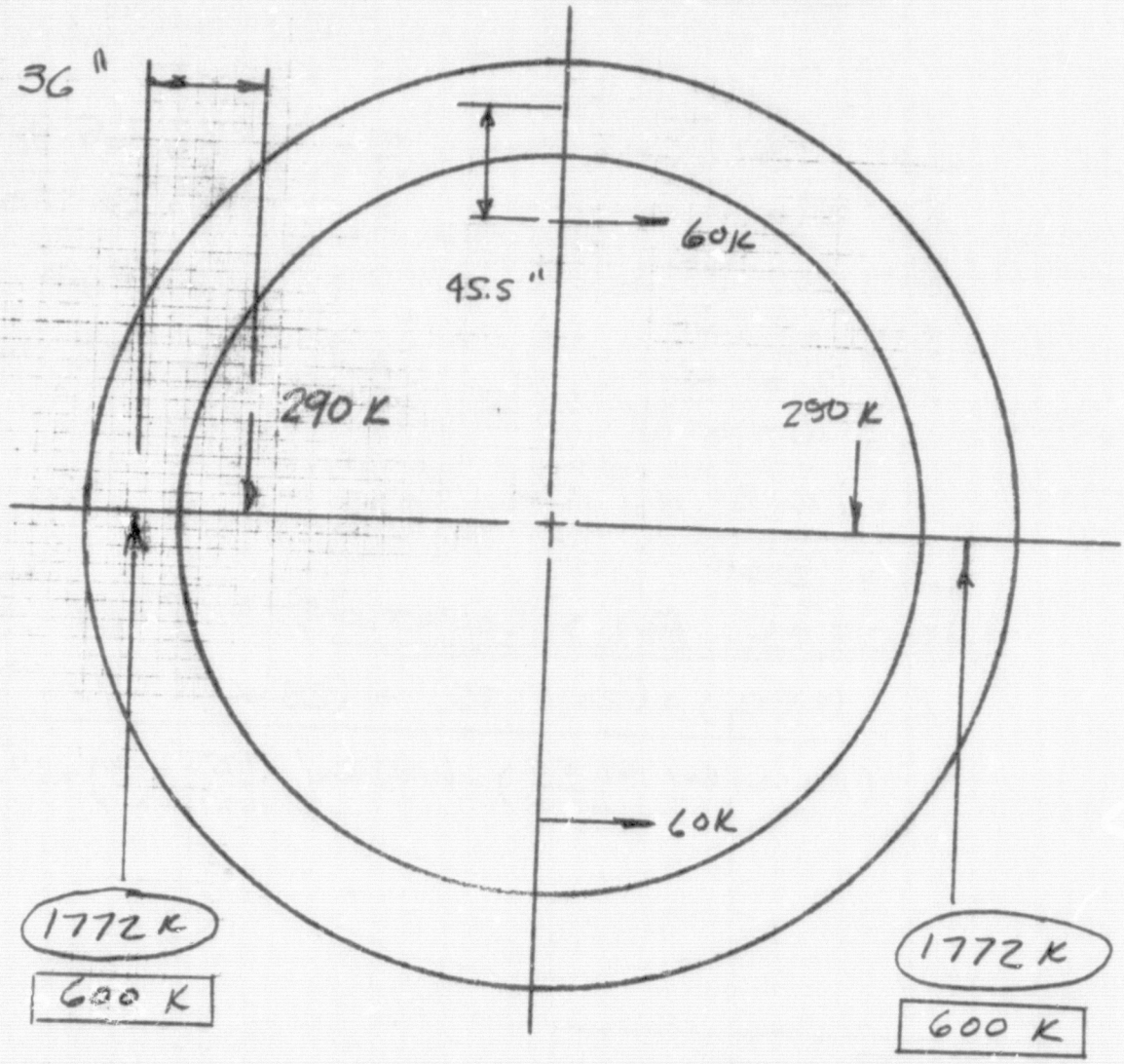
I = 9428.65 IN^4
E = 29 x 10⁶ PSI
ρ = .283 #/IN^3
A = 106.32 IN^2

NEUTRAL AXIS LOCATION

$$R = \frac{(2)(12) + (20)(1.25) + (28.66)(2.0)}{(28.66)\ln\left(\frac{167.75+2}{167.75}\right) + (1.25)\ln\left(\frac{167.75+2+20}{167.75+2}\right) + 12\ln\left(\frac{167.75+2+20-2}{167.75+2+20}\right)}$$

R = 175.816

LOAD CONDITIONS



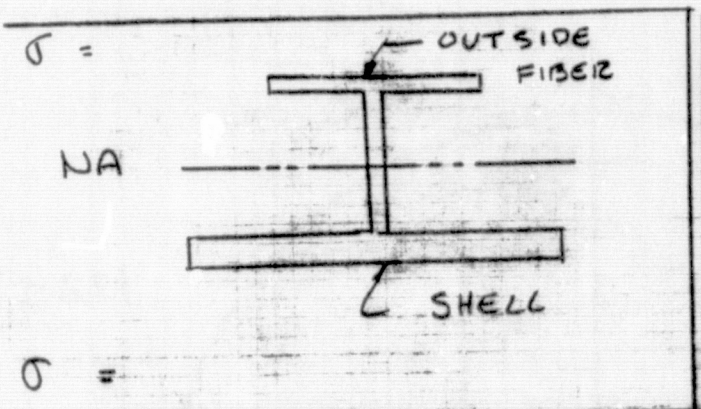
WEIGHT OF 9% NI STEEL

$W_S = 600 - 290 = \boxed{310\ K}$

WEIGHT OF WATER DURING HYDRO

$W_W = 1772 - 600 = \boxed{1172\ K}$

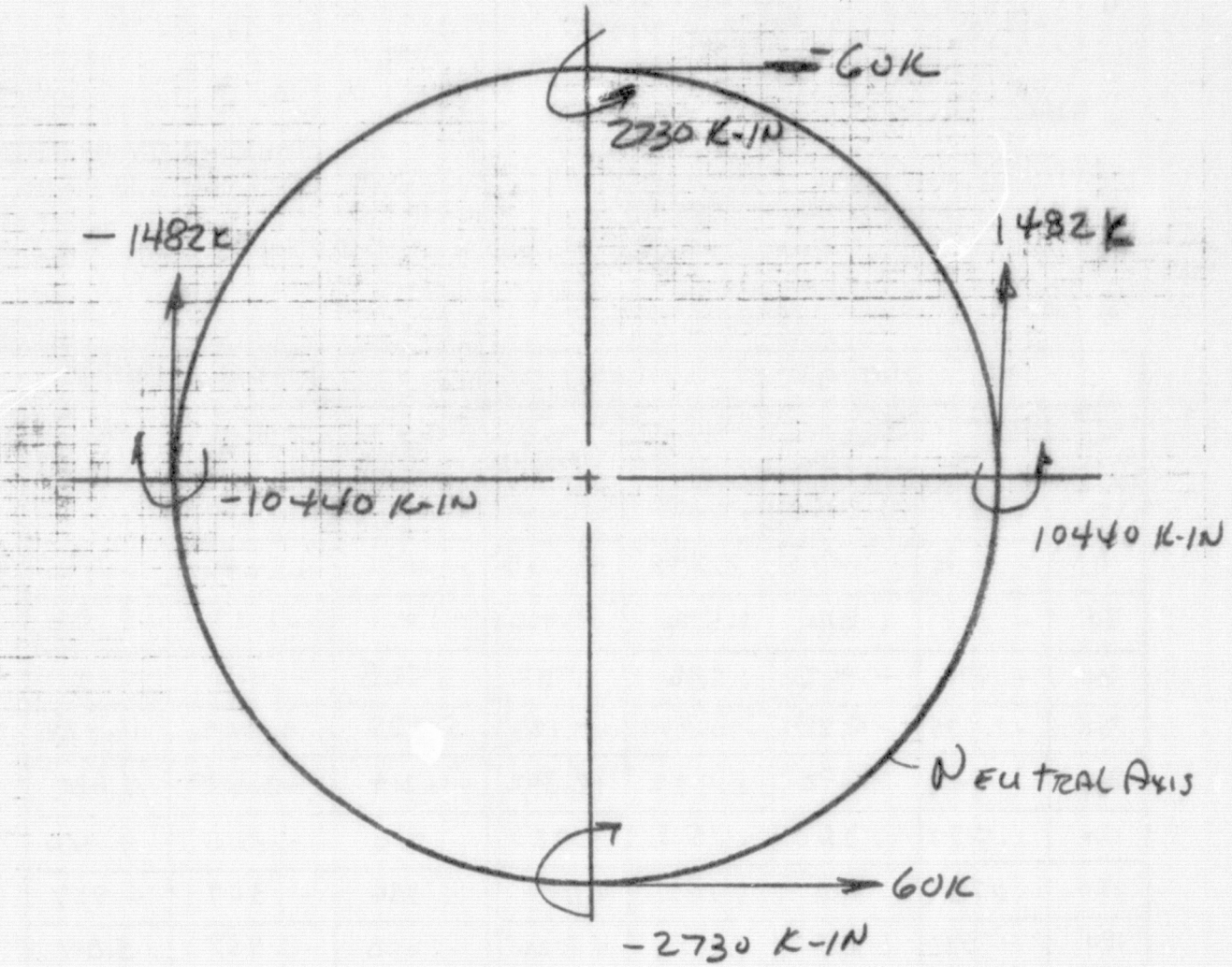
STRESS SUMMARY (OPPERATING)



REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

	OUT SIDE (KSI)				SHELL (KSI)		
Location θ	Axial	Bending	Combined	Combined w/press	Bending	Combined	Combined w/press
0	.391	-1.846	-1.456	1.914	1.068	1.459	8.719
0	-.174	2.473	2.299	5.669	-1.431	-1.605	5.655
30	-.221	1.816	1.596	4.966	-1.051	-1.272	5.988
60	-.676	-.912	1.588	1.782	.528	-.148	7.12
90	-1.275	-9.224	-10.499	-7.129	5.337	4.062	11.322
90	1.640	7.292	8.932	12.302	-4.219	-2.579	4.681
120	.090	.363	.453	3.823	-.210	-.120	7.140
150	.078	.668	.745	4.115	-.386	-.309	6.951
180	-.391	1.846	1.456	4.826	-1.068	-1.459	5.801
180	.174	-2.473	-2.299	1.071	1.431	1.605	8.865
210	.221	-1.816	-1.596	1.774	1.051	1.272	8.532
240	.676	.912	1.588	4.958	-.528	.148	7.408
270	1.275	9.224	10.499	13.869	-5.337	-4.062	3.198
270	-1.640	-7.292	-8.932	-5.562	4.219	2.579	9.839
300	-.899	-.363	-1.262	2.108	0.210	-.689	6.571
330	-.078	-.668	-.745	2.625	.386	.309	7.569
360	.391	-1.846	-1.456	1.914	1.068	1.459	8.719

COMPUTER MODEL FOR HYDROSTATIC CASE



GEOMETRICAL + MATERIAL PROPERTIES

$R = 175.816"$

$A = 106.32\ IN^2$

$C = 16.184\ IN$

$I = 9428.65\ IN^4$

$E = 29 \times 10^6\ PSI$

$\rho = .283\ \#/IN^3$

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HYDROSTATIC PRESSURE STRESS

OPERATING PRESSURE STRESSES

7,260 KSI, ON SHELL

3.370 KSI, OUT SIDE FLANGE

$$P_H = 1.5 \times 119 + \frac{62.4}{144}\left(\frac{41}{2} + \frac{28}{2}\right) = 193.45 \text{ PSI}$$

STRESS SCALE FACTOR $\frac{193.45}{119.0} = 1.626$

$(1.626)(7,260) = 11.805$ KSI, ON SHELL

$(1.626)(3.370) = 5.480$ KSI, OUTSIDE FIBER.

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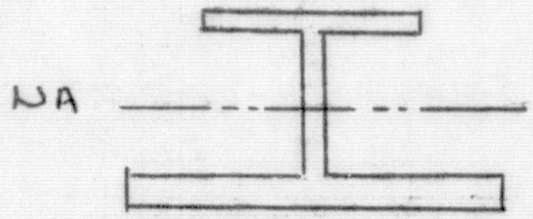
BY _____ DATE _____ SUBJECT _____ SHEET NO. 100 OF _____

CHKD. BY _____ DATE _____ JOB NO. _____

Stress Summary

σ =



σ =

	OUTSIDE (KSI)				SHELL (KSI)		
Location	Axial	Bending	Combined	Combined w/Press	Bending	Combined	Combined w/Press
0	2.145	-9.192	-7.047	-1.567	5.319	7.464	19.269
0	1.581	-4.873	-3.292	2.188	2.820	4.401	16.206
30	.380	.783	1.163	6.643	-.453	-.073	11.732
60	-2.982	8.023	5.042	10.521	-4.642	-7.624	9.181
90	-6.787	-9.224	-16.011	-10.531	5.337	-1.450	10.355
90	7.152	7.291	14.443	19.922	-4.219	2.933	14.738
120	3.204	-8.572	-5.369	.111	4.960	8.164	19.968
150	-.523	1.701	1.178	6.657	-.984	-1.507	10.297
180	-2.145	9.192	7.047	12.526	-5.319	-7.464	4.340
180	-1.581	4.873	3.292	8.772	-2.820	-4.401	7.404
210	-.380	-.783	-1.163	4.316	.453	.073	11.878
240	2.982	-8.023	-5.042	.438	4.642	7.624	19.429
270	6.787	9.224	16.011	21.491	-5.337	1.450	13.255
270	-7.152	-7.291	-14.443	-8.963	4.219	-2.933	8.871
300	-3.204	8.572	5.369	10.848	-4.96	-8.164	3.641
330	.523	-1.701	-1.178	4.302	.984	1.507	13.312
360	2.145	-9.192	-7.047	-1.567	5.319	7.464	19.269

BY_____ DATE_____ SUBJECT_____ SHEET NO. 101 OF_____

CHKD. BY_____ DATE_____ JOB NO._____

STRESS EVALUATION

I ASME CODE SECTION VIII DIV I

A. PRIMARY MEMBRANE + BENDING

1. OPPERATING

$P_m + P_b = 13.869 < 1.5 = 35.55$ KSI OK

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

2. Hydro

$P_m + P_b = 21.491 < 1.35 S_y$ (WELD) $= 70.8$ KSI OK

II AISC CODE

F_y of WELD = 52.5KSI

$F_B = 2/3\ F_y$

$F_T = 2/3\ F_y$ $= 2/3\ (52.5) = 35$ KSI

PEAK STRESS AT HYDRO = 21.491 KSI

THIS SUPPORT RING (S4 AND / OR S5) MEETS THE EVALUATION CRITERIA

DISCONTINUITY (PRESSURE AND THERMAL) STRESSES IN GATE VALVES

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

The discontinuity stresses in the gate valve have been calculated by closed form methods for several different geometry and boundary conditions. Pressure discontinuity stresses were calculated using method outlined in "Theory of Plates and Shells" by Timoshenko and Woinowsky-Krieger 2nd Edition page 555. The flexibility of the gate valve indicated that the edge ring would be forced to rotate along with the bulkhead flange. Therefore, there would be no sealing problem, due to incompatible rotations. A stress summary based on this forced rotation boundary condition is presented in Table 1. The forced rotation angle was taken from Bulkhead Finite element model with gates closed and steady state temperature distribution and LRC flange geometry. Temperature gradients thru the gate valve was calculated based on vertical plate natural convection film coeff. and linear temp. distribution. The temp. gradient obtained was so small (2°) that a thermal stress calculation was not even conducted.

After consulting with Fluidyne personnel it was decided to use 1" thick gates with ring only. The last entry in stress summary is for this geometry

and this reflects a O' ring rotation due to the stiffer bulkhead flanges that will be used in the bulkhead design.

The detail calculations follow the stress summary table.

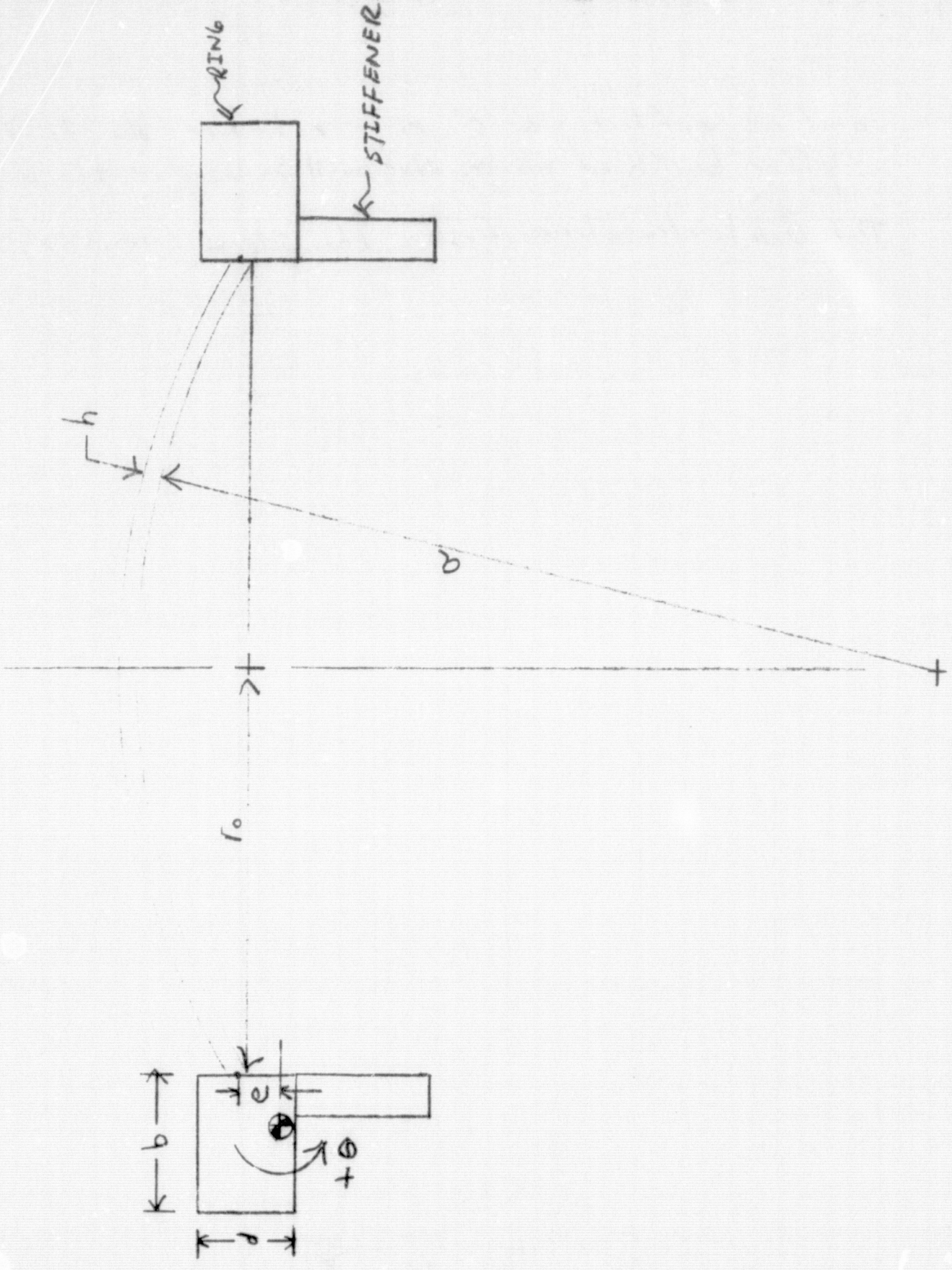

RING
STIFFENER
h
R
r₀
e
b
d
+θ

TABLE I STRESS SUMMARY

	h=.75 RING ONLY	h=1.10 RING + STIFFENER	h=.75 RING + STIFFENER	h=.92 RING ONLY	h=1.10 RING ONLY	ALLOWABLE
SHELL						
PRIMARY MEMBRANE	14280	10 710	14280	11641	10710	23 700
PEAK LOCAL MEMBRANE	25 340	16107	20704			47,500
LOCAL MEMBRANE @ $\sqrt{Rt}$	14035	10535	14079			34,900
SECONDARY STRESS	60 961	39 626	52 228	52433	51,535	52,500
RING						
SECONDARY STRESS	5688	5157	4584			52,500
ROTATION, °	+.037°	+.037°	+.037°	+.037°	0°	

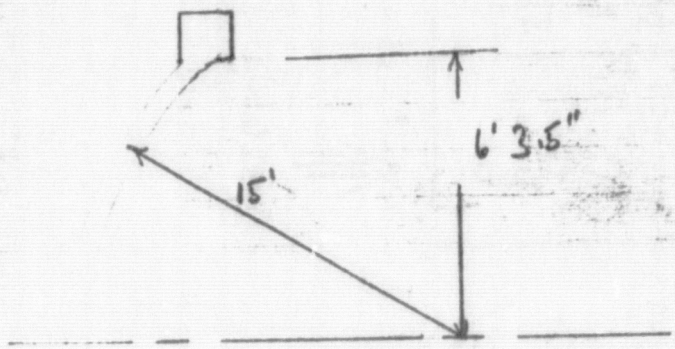
DESIGN

BY _____ DATE _____ SUBJECT _____ SHEET NO. 105 OF _____

CHKD. BY _____ DATE _____ JOB NO. _____

2/2/76

PRESSURE DISCONTINUITY STRESSES IN GATE VALVES



Need to determine Pressure Discontinuity Stresses. This can be done using "Theory of Plates and Shells" by Timoshenko and Woinowsky-Krieger 2nd Edition page 555.

REPRODUCIBILITY OF THE
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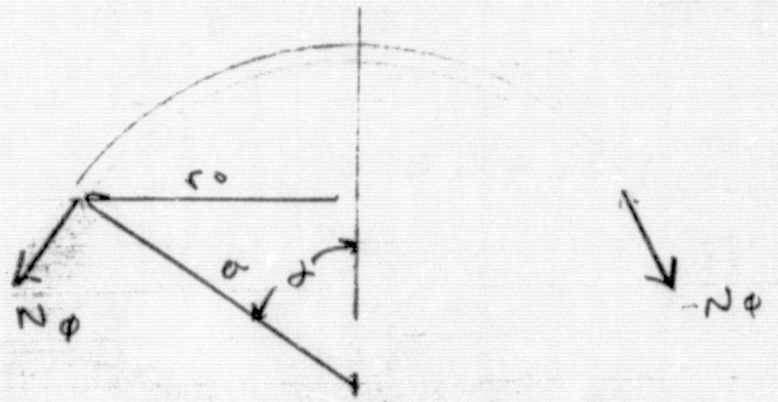
For the shell subject to Internal pressure P



$$N_\phi = N_\theta = + \frac{Pa}{2}$$

$$\delta_0 = \frac{a \sin\alpha}{Eh} (N_\theta - \nu N_\phi) = + \frac{(1-\nu) a^2 P \sin\alpha}{2Eh}$$ ← horiz. deflection of edge

$M_0 = 0$ for uniform internal pressure

$$\delta_1 = \frac{H_0 r_0^2}{Ebd} = H_0 = - \cos\alpha \, N_\phi)_{\phi=\alpha} = (-\cos\alpha) \frac{+Pa}{2}$$

$$\delta_1 = - \frac{Pa}{2} \frac{r_0^2}{Ebd} \cos\alpha$$

$$\delta = \frac{2\lambda^2 \sin\alpha}{Eh K_1} M_\alpha - \frac{a\lambda \sin^2\alpha \, H}{Eh} \left(K_2 + \frac{1}{K_1} \right)$$

$$V = \frac{-4\lambda^3}{Eh a K_1} M_\alpha + \frac{2\lambda^2 \sin\alpha}{Eh K_1} H$$

$$\lambda^4 = 3(1-\nu^2)(a/h)^2 \qquad K_1 = 1 - \frac{1-3\nu}{2\lambda} \cot(\alpha - \psi)$$

$$\delta_2 = \frac{H r_0^2}{Ebd} \qquad K_2 = 1 - \frac{1+2\nu}{2\lambda} \cot(\alpha - \psi)$$

$$V_2 = \frac{12 r_0^2}{Ebd^3}(m_\alpha + He)$$

$$\delta_0 + \delta = \delta_1 + \delta_2 + V_2 e \qquad (1)$$

$$V_0 + V = V_2 \qquad (2)$$

$$+ \frac{(1-\nu) a^2 P \sin\alpha}{2Eh} + \frac{2\lambda^2 \sin\alpha}{EhK_1} m_\alpha - \frac{a\lambda \sin^2\alpha}{Eh} H\left(K_2 + \frac{1}{K_1}\right)$$

$$= -\frac{Pa r_0^2 \cos\alpha}{2Ebd} + \frac{H r_0^2}{Ebd} + \frac{12 r_0^2}{Ebd^3}(m_\alpha + He)e$$

$$\left[\frac{2\lambda^2 \sin\alpha}{EhK_1} - \frac{12 r_0^2 e}{Ebd^3}\right] m_\alpha - \left[\frac{r_0^2}{Ebd} + \frac{12 r_0^2 e^2}{Ebd^3} + \frac{a\lambda \sin^2\alpha}{Eh}\left[\frac{K_2 + \frac{1}{K_1}}{K_1}\right]\right] H$$

$$= -\frac{(1-\nu) a^2 P \sin\alpha}{2Eh} - \frac{Pa r_0^2 \cos\alpha}{2Ebd}$$

$$0 \quad -\frac{4\lambda^3 m_\alpha}{Eh a K_1} + \frac{2\lambda^2 \sin\alpha H}{EhK_1} = \frac{12 r_0^2}{Ebd^3}(m_\alpha + He)$$

$$-\left[\frac{4\lambda^3}{Eh a K_1} + \frac{12 r_0^2}{Ebd^3}\right] m_\alpha = \left(\frac{12 r_0^2 e}{Ebd^3} - \frac{2\lambda^2 \sin\alpha}{EhK_1}\right) H$$

$$m_\alpha = -\frac{\left(\frac{12 r_0^2 e}{Ebd^3} - \frac{2\lambda^2 \sin\alpha}{EhK_1}\right) H}{\left(\frac{4\lambda^3}{Eh a K_1} + \frac{12 r_0^2}{Ebd^3}\right)}$$

For the LRC gate value geometry:

$a = 130''$ $h = .75in$ $\alpha = 26.92$ $P = 119\ psig$ $\nu = .3$

$b = 7\frac{1}{4}''$ $d = 5''$ $e = 1.5in$ $r_o = a\sin\alpha = 81.5in$

$E = 29 \times 10^6$

$\lambda^4 = 3(1-.3^2)\left(\frac{130}{.75}\right)^2 = 157248$ $K_1 = .9802$ $K_2 = .9209$

$\lambda^2 = 396.55$ $\lambda = 19.91$ $\lambda^2 = 7897$

$$m_\alpha = -\left[\frac{12\,(81.5in)^2(.75)in - 2\,(356.5)\sin 26.92^2}{(7.25in)(5in)^3} \cdot \frac{488.43}{.75in \cdot .9802}\right] \qquad H = +1.0914\,H_{in}$$

$$\frac{4\,(7897)}{(.75)(130)in^2 \cdot .9802} + \frac{12\,(81.5in)^2}{(7.25in)(5in)^3}$$

$$(488.43_{in} - 131.92)\,m_\alpha - \left[\frac{(81.5in)^2}{(7.25in)(5in)} + 197.89 + 1.09\frac{(130in)^2 \sin 26.92 (19.91)}{.75in}\right]$$

$$= -\frac{(1-.3)(81.5in)(130in)\left(119\frac{lbf}{in^2}\right)}{2(.75in)} - 119\frac{lbf}{in^2}\,\frac{(130in)(81.5in)^2 \cos 26.92}{2(5.in)(7.25in)}$$

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$$\frac{356.5}{in}\,m_\alpha - 2281.5\,H = -2.56 \times 10^6\,\frac{lbf}{in}$$

$$H = \frac{-2.564 \times 10^6\,\frac{lbf}{in}}{\left[\frac{356.5}{in}(1.09\ in) - 2281.5\right]} = 1355.\,\frac{lbf}{in}$$

$$m_\alpha = 19789.\,\frac{lbf\text{-}in}{in}$$

In order to check this solve for M_α & H for completely restrained spherical shell

From Sect 130, Ref 2.

$$M_\alpha = + \frac{P a^2 (1-\nu)}{4\lambda^2} = + \frac{119 \frac{lbf}{in^2} (190 in)^2 (1-.3)}{4(396.55)} = + 1701.5 \frac{lbf\text{-}in}{in}$$

$$H = + \frac{P a (1-\nu)}{2\lambda \sin\alpha} = + \frac{(119 \frac{lbf}{in^2})(190 in)(1-.3)}{2(19.91)\sin 26.92} = + 897.7 \frac{lbf}{in}$$

For completely constrained shell M_α should be larger and H is. The H forces are close. The finite solution obtained is in the right ball park.

Need to obtain force distributions

$$N_\alpha = - \cot(\alpha - \psi) C e^{-\lambda\psi} \sin(\lambda\psi + \pi)$$

$$M_\alpha = \frac{a}{\lambda\sqrt{2}} C e^{-\lambda\psi} \sin(\lambda\psi + \pi + \pi/4)$$

$\alpha = \alpha \Rightarrow \psi = 0$ $\quad N_\alpha = - H \cdot \cos\alpha = - (+1359) \frac{lbf}{in} \cos 26.92$

$M_\alpha = M_\alpha = - 1497$ lbf-in/in

$$-1208 \quad \frac{lbf}{in} = - \cot\alpha \, C \sin(\pi)$$

$$1497 \quad \frac{lbf\text{-}in}{in} = \frac{a}{\lambda\sqrt{2}} C \sin(\pi + \pi/4)$$

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$$C = \frac{1208}{\cot 26.52 \sin\gamma}\,\gamma = 613.7/\sin\gamma \quad \text{lbf/in}$$

1472 $\frac{\text{lbf}}{\text{in}} = \frac{180 \cdot N}{(15.51)\sqrt{2}}\left(\frac{613}{\sin\gamma}\,\frac{\text{lbf}}{\text{in}}\right)\sin(\gamma + \pi/4)$

$$.3769 = \frac{\sin(\gamma + \pi/4)}{\sin\gamma}$$

Trial & error soln:-

$\gamma = .6393\,\pi = 2.0084$ & $C = \frac{613}{\sin(.6393\,\pi)} = 677.$ lbf/in

$$N_\phi = -677 \text{ lbf/in} \cot(\alpha - \psi)\, e^{-19.91\psi} \sin(19.91\psi + .631\,\pi)$$

$$M_\phi = 4324 \cdot e^{-19.91\psi} \sin(19.91\psi + .8893\,\pi)$$

ϕ	N_ϕ	M_ϕ
26.9	-1208	1474
26.0	-743	117
24.0	-69	-968
23.6	7	-985
22.0	164	-770
20.0	161	-345
18.0	87	-76
16.0	25	29
14.0	-61	41
12.0	-14	24
10.0	-11	8
8.0	-5	1.4
6.0	-1.7	-2
4.0	1.7	-1.5
2.0	3.2	-1.7

Discontinuity Bending stress = $\frac{6M}{h^2}$ Discontinuity membrane = $\frac{N}{h}$

Peak stress occurs at ring/shell junction:-

$\sigma_b = \frac{(6)(1977)}{(.75)^2} = \pm 15755$ $\sigma_m = -\frac{1208}{.75} = -1611$

membrane stress in shell with no ring

$\sigma_{m\theta} = \sigma_{m\phi} = +\frac{P a}{2h} = +\frac{119\ lbf}{in^2}\frac{(180\ in)}{(2)(.75\ in)} = +14280$

$N_\phi = -\lambda\sqrt{2}\, C e^{-\lambda\psi} \sin(\lambda\psi + \psi - \pi/4)$

$M_\theta = \nu M_\phi$

$\underline{\phi = \alpha}$

$N_\theta = -(1771)\sqrt{2}\left(677\frac{lbf}{in}\right)\sin[.639 - 2.37] = -17915\ \frac{lbf}{in}$

$\sigma_{m\theta} = -23887$

$M_\phi = (.3)(1977) = 443\ \frac{in\text{-}lbf}{in}$ $\sigma_{b\phi} = \pm 9726$

Combined Total Stress:-

Convex Surface:

$\sigma_\phi = -15755 + -1611 + 14280 = -3086$

$\sigma_\theta = -23,887 - 4726 + 14280 = -14333$

$S = -14333 - 0 = -14333$ psi

Concave Surface:

$\sigma_\phi = 15,755 - 1611 + 14,280 = 28424$ psi

$\sigma_\theta = 4726 - 23887 + 14280 = -4881$

$S = 28424 - (-4881) = 29642$ psi ⇐ max stress

Stresses in Ring

$\varepsilon_\theta = \frac{H r_o}{E b d}$ $\quad \sigma = E \varepsilon_\theta$

$\sigma = \frac{H r_o}{b d} = \frac{(1355\ \text{lb/in})(81.5\ \text{in})}{(5\ \text{in})(7.25\ \text{in})} = +3046$ psi

Hoop stress due to Sandwich:-

$\sigma = \pm \frac{6 T r_o}{b d^2} = \frac{6 (M_a + H_c) r_o}{b d^2}$

$\sigma = 6 \frac{\left[-1427\ \frac{\text{lb-in}}{\text{in}} + (1355\ \text{lb/in})(1.5\ \text{in})\right] 81.5\ \text{in}}{(7.25\ \text{in})(5\ \text{in})^2}$

$\sigma = 9462$ ∴ Ring stresses are low

Rotation of edge:

$$V = -\frac{4\lambda^3}{Eha K_1} M_\alpha + 2\frac{\lambda^2 \sin\alpha}{Eh K_1} H$$

$$V = \frac{1}{25\pi^6}\left[-\frac{4\,(7897)}{(.75in)(.120in)}\,(1477\ lbf) + 2\,\frac{(3565.5)\sin(24.82)}{.75in}\,(1353\ \frac{lbf}{in})\right]$$

$$V = .0107\ rad\ or\ +.6110°$$

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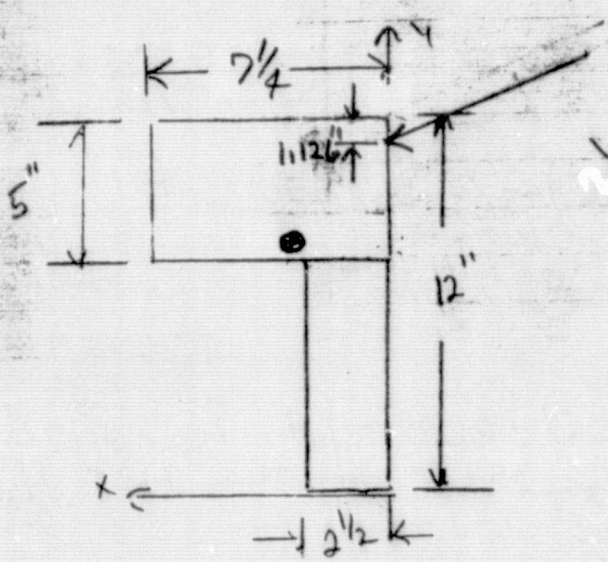
For the Fluidyne design:

$a = 130"$ $h = 1.0"$ $\alpha = \sin^{-1}\frac{6'9.5"}{15'} = 26.52°$

$P = 119$ psig $\nu = .3$ $r_o = 81.5$ in $K_1 = .9772$ $K_2 = .9087$

Need to determine properties of stiffened ring



$$y_c = \frac{(2.5)(7)(3.5) + (5)(7.25)(7+2.5)}{(2.5)(7) + (5)(7.25)}$$

$y_c = 7.55$ in

$$x_c = \frac{(2.5)(7)(1.25) + (5)(7.25)(3.625)}{(2.5)(7) + (5)(7.25)}$$

$x_c = 2.95$

$e = 12" - 1.126 - 7.55 = 3.3244$

$2.35 \tan 26.52° = 1.44$ ∴ since $1.44 \neq 3.3244$

membrane force of shell does not pass through centroid of ring.

will have to change equations to reflect stiffner ring.

Two new terms will be introduced:

A_n will replace bd

I_n will replace $\frac{bd^3}{12}$

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The formulas used to compute ring rotation (V_2) assume the cross section is compact, which the stiffened ring is not. However, they will still be used to get a handle on the stresses.

$$\lambda^4 = 3(1-.3^2)\left(\frac{180}{1}\right)^2 = 98452$$

$$\lambda^2 = 297.41 \qquad \lambda = 17.25 \qquad \lambda^0 = 5129$$

$$I_r = \frac{5^3(7.25)}{12} + (5)(7.25)(7+2.5-7.55)^2 + \frac{7^3(2.5)}{12}$$

$$+ (7)(2.5)(7.55-3.5)^2 = 571.86 \text{ in}^4$$

$$A_r = (5)(7.25) + 7)(2.5) = 53.75 \text{ in}^2$$

$$M_\alpha = -\left[\frac{(81.5)^2(3.32)}{571.86} - \frac{2(297.41)\sin(26.92)}{1.0 \quad .9772}\right]H = 1.85\,H$$

$$\frac{4(5129)}{(1)(180)(.9772)} + \frac{(81.5)^2}{571.86}$$

$$(275.58 - 38.57)M_\alpha - \left[\frac{(81.5)^2}{(53.75)} + 128 + \frac{1.193(4)(1)\sin^2 26.92(17.25)}{1}\right]H$$

$$= -\frac{(1-.3)(81.5)(180)(11.9}{(2)(1)} - \frac{11.9(180)(81.5)^2\cos(26.92)}{(2)\,53.75}$$

$$237.M_\alpha - 1481.H = -1.79\times10^6$$

$$H = \frac{-1.79\times10^6}{237.(1.85) - 1481.} = 1717 \frac{lbf}{in}$$

$$m = 3175 - \frac{lbf\text{-}in}{in}$$

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$N_\phi = -H\cos\alpha = -(1717)\cos 26.92 = -1531$

$$C = -\frac{(-1531)}{\cos\alpha \sin\tau} = \frac{777.37}{\sin\tau}$$

$$\frac{(3125)(17.25)\sqrt{2}}{(180)(777.37)} = \frac{\sin(\tau + \pi/4)}{\sin(\tau)} = .5535$$

From Trial & error $\tau = .570\pi \Rightarrow C = \frac{777}{\sin(.570\pi)}$

$\tau = .570\pi \quad C = 796.3 \frac{lbf}{in}$

$m_\phi = 3125 \quad \sigma_{b\phi} = \frac{6(3125)}{(1)} = \pm 19050$ psi

$m_\theta = \nu m_\phi = \sigma_{b\theta} = \nu \sigma_\phi = \pm 5715$

membrane pressure stress $\rightarrow + \frac{pa}{2h} = +10,710$

$N_\phi = -1531 \quad \sigma_{m\phi} = -1531$

$N_\theta = -(17.25)\sqrt{2}(+796)\sin[(.57-.25)\pi] = -16,396$

$\sigma_{m\theta} = -16,396$

Maximum Stress occurs at concave surface:-

$\sigma_\phi = 19,050 - 1531 + 10,710 = -28,229$

$\sigma_\theta = 5715 - 12,396 + 10,710 = 29$

$S = 28,229$

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$$V = \frac{1}{29\times10^6}\left[\frac{-4(5129)(3173)}{(1)\ 130,972} + \frac{2(257.41)\sin(26.52)(1717)}{,972\ (1)}\right]$$

$V = +.0035$ rad or $.203°$

∴ with the larger stiffner ring and thicker shell the stresses are about the same as the LRC design. However, the rotation of the ring has been reduced by a third.

The stresses are much lower than those predicted by fluidyne (42,000) and the deflections are larger (.077°)

For 3/4" shell and stick flange

$\lambda = 19.91 \quad \lambda^2 = 396.55 \quad \lambda^3 = 7897$

$K_1 = .9802 \quad K_2 = .9209 \quad e = 3.45$

$$m_\alpha = -\frac{\left[\frac{31.5^2(3.45)}{571.86} - 2\frac{(396.55)\sin(26.52)}{(.75)(.9802)}\right]}{\left[\frac{4(7897)}{(.75)(180)(.9802)} + \frac{31.5^2}{571.86}\right]} = 1.79\ H$$

$$(488.43 - 40.07)\, m_\alpha - \left[123.58 + 139.22 + \frac{(1.94)180\sin^2 26.92(19.91)}{.75}\right]$$

$$= -1.99 \times 10^6$$

$$H = \frac{-1.99\times10^6}{(448.36)(1.79) - 2162} = 1464 \frac{lbF}{in}$$

$M_\alpha = 2620$

$$\sigma_{max} = \frac{(6)(2620)}{.75^2} + 14280 = 42230\ psi$$

EFFECT OF BULKHEADS

The previous analysis assumed that stiffening ring was free to rotate; However, the gate is actually "dogged" to the bulk head and the ring will probably follow the bulk Head Flange rotations. Need to calculate stresses for this forced displacement.

let V_F = Forced rotation on gate

assume "dogs" let ring radially expand or contract

$$\delta_0 + \delta = \delta_1 + \delta_2 + V_f e$$

$$V_0 + V = V_f$$

$$0 - \frac{4\lambda^3 m_\alpha}{E h a K_1} + \frac{2\lambda^2 \sin\alpha}{E h K_1} H = V_F$$

$$m_\alpha = \frac{E h a K_1}{4\lambda^3}\left[\frac{2\lambda^2 \sin\alpha}{E h K_1} H - V_F\right]$$

$$m_x = \left[\frac{a \sin\alpha}{2\lambda} H - \frac{E h a K_1}{4\lambda^3} V_F\right]$$

$$\frac{(1-\nu) a^2 \rho \sin\alpha}{2Eh} + \frac{2\lambda^2 \sin\alpha}{E h K_1} m_\alpha - \frac{a\lambda \sin^2\alpha}{Eh} H\left(K_2 + \frac{1}{K_1}\right)$$

$$= -\frac{\rho_a r_a^2 \cos\alpha}{2Eb d} + \frac{H r_0^2}{Ebd} + V_f e$$

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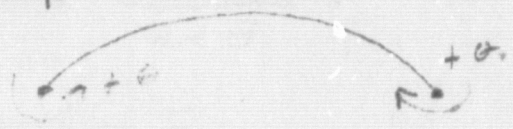
$$\frac{2\lambda^2 \sin\alpha}{E h K_1} M_\alpha - \left[\frac{a\lambda \sin^2\alpha}{Eh}\left(K_2 + \frac{1}{K_1}\right) + \frac{r_0^2}{Ebd} \right] H$$

$$= -\frac{(1-\nu) a^2 p \sin\alpha}{2Eh} - \frac{p a r_0^2 \cos\alpha}{2Ebd} + V_{Fe}$$

LRC Design - steady state temp



$V_f = +6.458 \times 10^{-4}$ rad

$$m_\alpha = \left[\frac{(180\text{in})\sin(26.92)}{2(19.91)} H - \frac{\left(29\times10^6 \frac{\text{lbf}}{\text{in}^2}\right)(.75\text{in})(180\text{in})(.5802)(6.458\times10^{-4})}{4(7897)} \right]$$

(2.0466 over the first fraction; 78.22 over the second)

$$m_\alpha = 2.0466\,H - 78.46$$

$$\frac{(2)(396.55)(\sin 26.92)}{.75(.9802)}\left[2.0466H - 78.22\right] - \left[\frac{(1.94)(180)(19.91)\sin^2 26.92}{.75} + \frac{81.5^2}{(7.25)(5)}\right]H$$

(+72.43 over the first fraction; 1906 over the second; 183.23 over the last)

$$= -2.5\times10^6 \frac{\text{lbf}}{\text{in}} + (6.457\times10^{-4})(1.5)\,29\times10^6$$

$$H = \frac{-2.49\times10^6 \text{ lbf/in}}{-1084} = 2300 \frac{\text{lbf}}{\text{in}}$$

$m_\alpha = 4629$

for $V_f = 0$ $\quad H = 2362 \quad m_\alpha = 4756$

$$\text{Peak stress} = \frac{(4629)6}{.75^2} - \frac{2300}{.75} + 14280 = 60589$$

REPRODUCIBILITY OF THE
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LRC – TRANSIENT TEMP:-

VF = – .0079 rad

$m_\alpha = 2.0466H + 954$

$H = \frac{-3.37 \times 10^6}{-1084} = 3109 \qquad m_\alpha = 6342$

$T_{peak} = \frac{6362(6)}{(.75)^2} - \frac{3109}{.75} + 14280 = 77,996$

Fluidyne – design – steady state temp:-

$m_\alpha = (2.0466)\frac{(19.91)}{(17.25)}H - (78.22)\frac{(7897)}{(5129)}\left(\frac{.5772}{.9802}\right)\left(\frac{1}{.75}\right)$

$m_\alpha = 2.36H - 160.1$

$\frac{(2)(297.41)(\sin 26.92)}{(.9772)}\left[2.36H - 160\right] - \left[(1.53)(80)(17.25)\sin^2(26.92) + \frac{81.5^2}{(7.25)(5)}\right]$

$= -1.75 \times 10^6 + (29.6)\,6.457 \times 10^{-4}(1.5)$

$H = 2257 \qquad m_\alpha = 5165$

$T_{peak} = (6)(5165) - 2257 + 10,710 = 39447$

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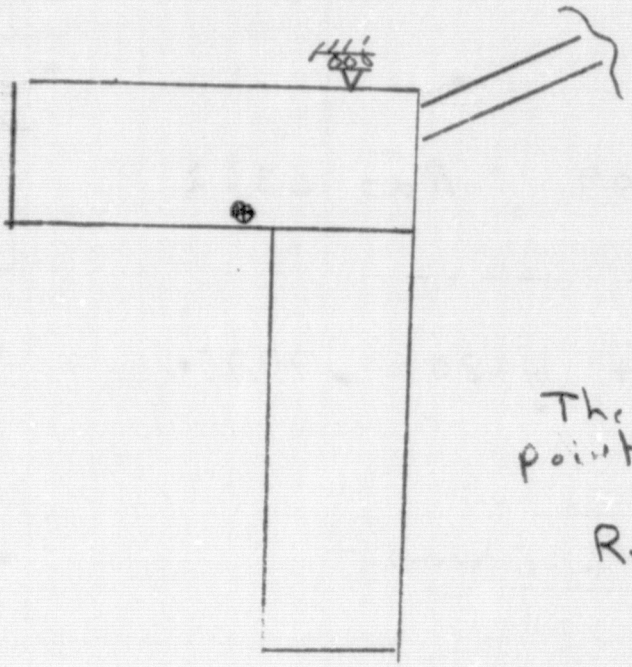
Fluidyne Design with finite element B.C.



Need to take into account that fixed point does not act through centroid of ring. Need to include this new moment in V_2

The vertical reaction at the fixed point is:

$$R_V = \frac{P r_o}{2}$$

$$V_2 = \frac{12 r_o^2}{E b d^3}\left(M_\alpha + H e - \frac{P r_o}{2} \varepsilon_x\right)$$

$$\varepsilon_x = 2.85 - 1.25 = 1.60 \text{ in}$$

For the fluidyne design:

$$M_\alpha = 1.85 H - \frac{(119)(81.5)^3(1.6)}{(571.86)(-128.25)} = 1.85H + 1405.3$$

$$H = \frac{-1.79 \times 10^6 - \frac{(119)(81.5)^3(1.6)(3.32)}{571.86} - (237)(1405.3)}{(237)(1.85) - 1481}$$

$$H = \frac{2.72 \times 10^6}{1042.55} = 2610 \qquad M_\alpha = 6234.5$$

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$$T_o = (6234.5)\,6 - 2610 + 10.710 = 45507$$

From fluidyn/a finite element Program:

$T_{11} = 42,500$

$$V = \left[\begin{matrix} (-4)(5129) \\ (180)(9772) \end{matrix} \right] 62345 + (2)(257.91) \sin 21.52 \; 2610 \Big] / 29 \times 10^6$$

$V = -.000272$ rad or $-.016°$

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TEMP. GRADIENT THRU GATE VALVES

Need to determine temp. grad thru gates in order to estimate thermal stresses. The gates are to be designed to withstand the full temperature difference (560-160).

Film coef.

The film coefs will be estimated based on relations for a vertical plate.

From Ref. 2 pg 364

$$N_{NUL} = C (N_{GR} N_{PR})^m$$

$$N_{GR} = \frac{\ell^3 \rho^2 g \beta \Delta t}{\mu^2}$$

$\ell = 163$ in

$\rho = \frac{P}{RT}$ $\quad R = 55.2 \frac{ft\text{-}lbf}{lbm\ ^\circ R}$

$\beta = \frac{1}{T}$

REPRODUCIBILITY OF THE
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For the Convex side:

$T = 560°R \quad P = 1\ ATm$

$$\rho = \frac{(14.7\ lbf/in^2)}{\left(53.2\ \frac{ft\cdot lbf}{lbm\cdot R}\right)(560°R)\ \frac{12\ in}{ft}} = 3.56 \times 10^{-5}\ \frac{lbm}{in^3}$$

$$\beta = \frac{1}{560} = .0018 \qquad N_{PR} = .706 \qquad K = .01566\ \frac{Btu}{hr\,ft\,°F}$$

$$\mu = C_1 \frac{T^{3/2}}{T + C_2} = 2.16 \times 10^{-8}\ \frac{slugs}{ft\text{-}sec\sqrt{R°}}\left[\frac{560^{3/2}}{560 + 198}\right]$$

$$\mu = 3.847 \times 10^{-7}\ \frac{slugs}{ft\text{-}sec}\ \frac{32.1\ lbm}{slug} = 1.2377 \times 10^{-5}\ \frac{lbm \times ft}{ft\text{-}sec \times 12\ in}$$

assume $\Delta t = 50°F$

$$N_{GR} = \frac{(163\ in)^3 \left(3.76 \times 10^{-5}\ \frac{lbm}{in^3}\right)^2 \left(\frac{386\ in}{sec^2}\right)(.0018)(50)}{\left(1.0314 \times 10^{-6}\ \frac{lbm}{in\text{-}sec}\right)^2} = 2.22 \times 10^{11}$$

for $10^9 \le N_{GR} < 10^{12} \quad C = .129 \quad m = 1/3$

$$N_{Nu} = .129\left(.706 \times 2.22 \times 10^{11}\right)^{1/3} = 695$$

$$h = \frac{N_{Nu}}{L} \times K = \frac{(695)}{163\ in}\ .01566\ \frac{Btu}{hr\,ft\,°F}\ \frac{12\ in}{ft} =$$

$$h'_c = .8\ \frac{Btu}{ft^2\text{-}hr\,°F}$$

for the concave side:-

$T = 160°R \quad P = 115 PSIG$

$$\rho = \frac{(119)}{(53.7)(160)(12)} = 1.123 \times 10^{-3} \frac{lbm}{in^3}$$

$$\beta = \frac{1}{160} = .0135 \qquad N_{Pr} = .739 \qquad K = .01045$$

$$\mu = (2.16 \times 10^{-8}) \left[\frac{160^{3/2}}{160 + 184} \right] \frac{(32.17)}{12} = 3.41 \times 10^{-7}$$

Assume $\Delta t = 50°$

$$N_{GR} = \frac{(163)^3 (1.123 \times 10^{-3})^2 (386)(.0135)(50)}{(3.41 \times 10^{-7})^2} = 5.66 \times 10^{15}$$

This is outside range of equations so the following will still be used

$$h = (.14) \left[\frac{(.739)(5.66 \times 10^{15})}{163} \right]^{1/3} (.01045)(12) = 16.0 \frac{Btu}{ft^2 - hr - °F}$$

Heat Balance:

160 | 160°

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$$Q = \frac{560 - 160}{\frac{1}{16.0\ \frac{Btu}{ft^2\text{-}hr}} + \frac{.75\ in}{1.33\ \frac{Btu}{hr\text{-}in\text{-}°F}\ \frac{144\ in^2}{ft^2}} + \frac{1}{1.8\ \frac{Btu}{ft^2\text{-}hr\text{-}°F}}} = 304.6\ \frac{Btu}{ft^2\text{-}hr}$$

Temp grad in wall:

$$Q = \frac{KA\,\Delta T}{\Delta x} \qquad \Delta T = \frac{Q\,\Delta x}{KA}$$

$$\Delta T = \frac{\left(304.6\ \frac{Btu}{ft^2\text{-}hr}\right)(.75\ in)}{\frac{1.33\ Btu}{hr\text{-}in\text{-}°F}\ \frac{144\ in^2}{ft^2}} = 1.19\ °F$$

Temp of Gate:

$$Q = h\,(T_o - T_s)$$

$$T_o - T_s = Q/h = \frac{303}{16} = 18.93$$

$$T_s = 160 + 19 = 179°R \text{ or } -281°F$$

Need to reiterate on Δt

For inside $\Delta t = 560 - 179 = 380$.
For outside $\Delta t = 19 - 20°$

$$h_i = (.18)\left(\frac{380}{50}\right)^{1/3} = 1.57\ \frac{Btu}{ft^2\text{-}hr\text{-}°F}$$

$$h_o = (16)\left(\frac{20}{50}\right)^{1/3} = 14.0$$

$$Q = \frac{400}{\frac{1}{14} + \frac{1}{1.57} + \frac{.25}{(1.33)14}} = 561.6 \ \frac{Btu}{hr\ ft^2}$$

$$\Delta t = 1.19\left(\frac{561.6}{393}\right) = 2.21\ ^\circ F \Leftarrow \therefore \text{thermal stress will be negligible}$$

$$(T_o - T_s) = 561.6 / 14.0 = 40$$

$$T_s = 200\ ^\circ R \text{ or } -260\ ^\circ F$$

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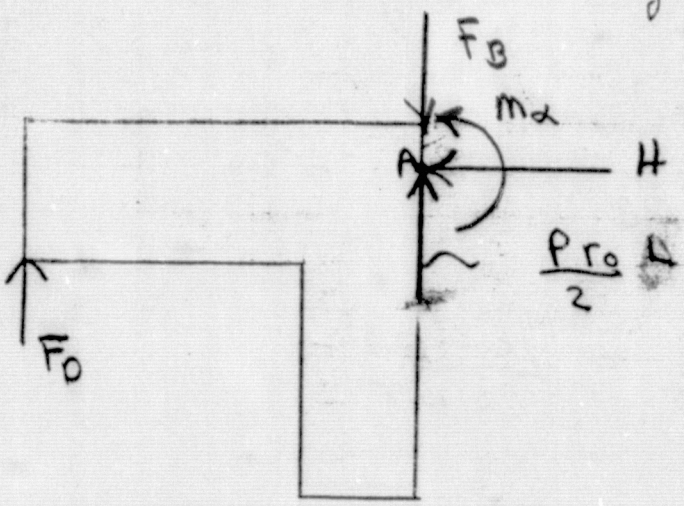
7/21/76

REQUIRED FORCES ON RING

Reactions from dog (F_D) & bulkhead (F_B)



$L = (2)\pi(8.5\,in) = 512\,in$

32 dogs

$$\Sigma F \quad 32F_D + \frac{P r_0 L}{2} - F_B = 0$$

$$\Sigma m_A \;) \quad -7.25F_D + M_\alpha L = 0$$

$$F_D = \frac{M_\alpha L}{(32)(7.25)}$$

For Fluidyne design i- $M_\alpha = 5165$ steady state forced rotation

$$F_D = \frac{\left(5165\,\frac{lbf\text{-}in}{in}\right)(512\,in)}{(32\,dogs)(7.25\,in)} = 11,400\ lbf$$

From Fluidyne Design Manual Vol III sect 2.2.3 dog pre-load is 36,000 lbf to 39,000 lbf with belleville springs in dogs can forge ring to follow bulkhead flange, and the forced rotation boundary condition approximates the gate values Sect.

7/22/76

Stress Distribution for LRC Design with Forced Rotation from Steady State

From previous calculations

$M_\alpha = 4629 \qquad H = 2300$

$$C = -\frac{(2300)\cos\alpha}{\cancel{\cos\alpha}\ \sin\sigma} = \frac{1041.32}{\sin\sigma}$$
$$\sin\alpha$$

$$\frac{4629(19.91)\sqrt{2}}{(180)(1041.32)} = \frac{\sin(\sigma + \pi/4)}{\sin\sigma} = .6954$$

$\sigma = .505 \qquad C = 1041.45$

Φ	N_α	M_α
26.9	-2053	4633
26.0	-1478	2149
24.0	-444	-573
22.0	69	-975
20.0	194	-604
18.0	145	-221
16.0	65	-19
14.0	10	41
12.0	-13	36
10.0	-15	17

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Primary local membrane stress Limit:

$L \leq \sqrt{rt} = (180in \cdot .75in)^{1/2} = 11.62$

$L = r\theta \qquad \theta = \frac{L}{r} = \frac{11.62}{180} = .0645$ rad or $3.7°$

$\therefore$ Comput. stress $\Theta \quad 26.52 - 3.7 = 23.22°$

for $\Phi = 23.22° \qquad \psi = .0645$ rad

$m_\phi = -903 \qquad N_\phi = -184 \qquad m_\theta = (.3)(-903) = -271$

$N_\theta = -\lambda\sqrt{2}\, C e^{-\lambda\psi} \sin(\lambda\psi + \gamma - \pi/4)$

$N_\theta = (-19.91)\sqrt{2}\,(1041.45)\, e^{-19.91(.0645)} \sin[(19.91)(.0645) + .5a - .25\pi]$

$N_\theta = -7068$

Stress state:

convex surface:

$T_\phi = -\frac{(-903)6}{(.75)^2} + \frac{(-184)}{.75} + 14280 = 23,680$ ⇐

$T_\theta = -\frac{(-271)6}{(.75)^2} - \frac{7068}{(.75)} + 14280 = 7746$

concave surface

$T_\phi = +\frac{(-903)6}{(.75)^2} - \frac{(184)}{.75} + 14280 = 4403$

$T_\theta = +\frac{(-271)6}{.75^2} - \frac{(7068)}{.75} + 14280 = 1563$

mid surface: $T_\phi = 14035 \qquad T_\theta = 4856$

Peak Discontinuity Stress

for $\Phi = 26.92$ $\psi = 0$

$M_\phi = 4633$ $N_\phi = -2053$ $M_\theta = .3(4633) = 1350$

$N_\theta = -(19.91)\sqrt{2}(1041.05)\sin(.505 - .25)\pi = -21058$

Convex surface:

$T_\phi = -\frac{(4633)6}{.175^2} - \frac{2053}{.175} + 14280 = -37,876$

$T_\theta = -\frac{(1350)6}{.175^2} - \frac{21,058}{.175} + 14280 = -28,624$

Concave surface

$T_\phi = \frac{(4633)6}{.175^2} - \frac{2053}{.175} + 14280 = 60,561$

$T_\theta = \frac{(1390)6}{.175^2} - \frac{21,058}{.175} + [illegible] = 1029$

Mid surface (membrane)

$T_\phi = 11543$ $T_\theta = -13,797$

Ring Stress

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$$T = \frac{E \Delta r_0 C}{r_0^2} + \frac{H r_0}{A r}$$

$$T = \frac{(29\times10^6)(6.458\times10^{-4}\ \text{rad})(2.25\text{in})}{81.5\text{in}} + \frac{2300\ \frac{\text{lbf}}{\text{in}}(81.5\text{in})}{(5)(7.25)} = 5688$$

Fluidyne design steady state

Peak Discontinuity: $T = .51$ $C = 1022$

$M_\phi = 5165$ $N_\phi = -\cos 26.92\,(2259) = -2074$

$M_\theta = 1550$ $N_\theta = -18181$

Concave Surface

$$T_\phi = \frac{(5165)6}{(1)} - \frac{2074}{(1)} + 10710 = 39626$$

$$T_\theta = (1550)6 - 18181 + 10710 = 1829$$

membrane

$T_\phi = 8636$
$T_\theta = -7471$

Local membrane $\Phi = 26.9 - \frac{\sqrt{(80)(1)}}{180}\,\frac{360}{2\pi} = 22.65$

$N_\phi = -175$

$$N_\theta = -(17.25)\sqrt{2}\,(1022)\,e^{-17.25(.0745)}\sin\left[17.25(.0745)+(.51-.25)\pi\right]$$

$N_\theta = -5944$

$$T_\phi = \frac{-175}{1} + 10{,}710 = 10535$$

$T_\theta = -5944 + 10{,}710 \quad 4766$

Ring Stress:-

$$T = \frac{(29\times10^6)(6.458\times10^{-4})}{(81.5)}\,7.55 + \frac{2257\,(81.5)}{53.75} = 5757$$

7/23/76

LRC / STIFFENED DESIGN STEADY STATE

$M_\alpha = 2.0466\,H - 78.22$

$488.43\,[2.0466H - 78.22] - \left[1900 + \frac{815^2}{5375}\right]$

$= -1.99\times10^4 + (6.458\times10^{-4})(1.5)\,29\times10^6$

$H = \frac{-1.924\times10^6}{999.62 - 2024} = 1879$

$M_\alpha = 3767$

$T = .505 \qquad C = 850.8$

Peak Discontinuity Stress

$\phi = \alpha$

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

$M_\phi = 3767 \qquad M_\theta = 1130$

$N_\phi = -1675 \qquad N_\theta = -17203$

Concave Surface

$T_\phi = \frac{3767(6)}{.175^2} - \frac{1675}{.175} + 14280 = 52228$

$T_\theta = \frac{(1130)6}{.175^2} - \frac{17203}{.175} + 14280 = 3396$

LOCAL MEMBRANE $\alpha = 23.22$

$N_\phi = -150.6$

$N_\theta = -5774$

$\sigma_\phi = \frac{-150.6}{.75} + 14280 = 14079$

$\sigma_\theta = \frac{-5774}{.75} + 14280 = 6581$

Peak Local Membrane

$12046 + 8657 = 20704$

Ring stress:

$\sigma = \frac{29 \times 10^6 (6.458 \times 10^{-4})(.55)}{81.5} + \frac{(1225)(81.5)}{53.75} = 4584$

OPTIMIZATION OF GATE DESIGN

Need to determine t_i t_o that will give peak stress of 52,500.

$$\left(\frac{t_o}{t_i}\right)^2 60{,}961 = 52{,}500 \Rightarrow t_i = .8064$$

$\therefore$ try .8125

$$\lambda^4 = 3(1-.3^2)\left(\frac{180}{.8125}\right)^2 = 133{,}596$$

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

$$\lambda^2 = 366.04 \qquad \lambda = 19.13 \qquad \lambda^3 = 7003$$

$$m_\alpha = \frac{(1.80)\sin(26.92)}{(2)(19.13)} H - \frac{(29\times10^6)(.8125)(180)(.5302)(6.458\times10^{-9})}{4(7003)}$$

$$m_\alpha = 2.13 H - 95.84$$

$$\frac{(2)(366.04)(\sin 26.92)}{(.7123)(.9802)}\left[2.13H - 95.84\right] - \left[\frac{(1.94)(180)(69.13)\sin^2 26.92}{.8125}\right.$$

$$\left. + \frac{81.5^2}{7.125(5)}\right] H = -\frac{(1-.3)(81.5)(180)119}{(2)(.8125)} - \frac{119(180)(81.5)^2(\cos 26.92)}{(2)(5)7.125}$$

$$+ (6.458\times10^{-4})(1.5)\,29\times10^6$$

$$H = \frac{-2.43 \times 10^6}{-982} = 2478$$

$$m_\alpha = 5183$$

$$\text{Peak Stress} = \frac{(6)(5183)}{(.8125)^2} - \frac{2478}{.8125} + 13182$$

$$\sigma_{peak} = 57240 \text{ psi}$$

looks like "square" ratioing does not work..
try linear ratio

$$\frac{.75}{.8125}\ 60,589 = 55,728$$

$$\therefore \text{ new thickness} \approx \frac{57,240}{52,500}\ \frac{57,240}{55,728}\ .8125 = .9066$$

try $t = .9$

$$\lambda^4 = 3(1-.3^2)\left(\frac{180}{.9}\right)^2 = 109,200 \quad \lambda^2 = 330 \quad \lambda = 18.17$$

$$\lambda^3 = 6007 \quad K_1 = .9783 \quad K_2 = .5133 \quad K_2 + \frac{1}{K_1} = 1.935$$

$$m_\alpha = 2.24H - 123.5$$

$$H = \frac{-2.36 \times 10^6}{-864.39} = 2729 \quad m_\alpha = 5989$$

$$\sigma_p = \frac{(6)(5989)}{.9^2} - \frac{2729}{.9} + 11500 = 53,233$$

$\therefore$ $t = .92$ $\quad \lambda^4 = 104504$ $\quad \lambda^2 = 323.27$ $\quad \lambda = 17.98$

$\lambda^2 = 5812$

$M_x = 2.266\,H - 130.51$

$$H = \frac{-2.344 \times 10^{-6}}{-841.55} = 2785 \qquad M_x = 6180$$

$$\sigma_{pm} = \frac{(6180)6}{.92^2} - \frac{2785}{.92} + 11641 = 52,423 \Leftarrow \text{peak}$$

$\therefore$ get. dish would be .92 in thk

extra cost $59,400

$\therefore$ it is not cost effective to increase get. thk.

$\therefore$ Best Design :-

$t = .75$ in with $7'' \times 2\tfrac{1}{2}''$ extra flang. (stiffener)

REFERENCES

1. "Theory of Plates and Shells" Timoshenko and Woinowsky-Krieger 2nd Edition

2. "Heat Transfer" - Chapman 2nd Edition

304 Cat. valve cut.

dish surface area $(A_d) = \frac{4\pi r^2}{2}\frac{\alpha}{90}$

$A_d = \frac{(4)\pi(180.46)^2}{2}\frac{(26.92)}{90}\frac{1}{(144)} = 425\ ft^2$

$V_d = (425\ ft^2)\left(\frac{.76}{12}\right)(2) = 53.83\ ft^3$

flanges

$V = 2\left[\frac{2(81.5 + 3.625)\pi(5)(7.25)}{1728}\right]$

$V_f = 22.44\ ft^3$

$wt = [22.44 + 53.83]\ 450 = 37,397\ \#$

Ti Ni Sat.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

$V_d = 53.83 \ldots =$

$V_f = 22.44 + 2\left[\frac{2\pi(81.5 + 1.25)(7)\ 2.5}{1728}\right] = 32.97$

$wt = (54 + 33)\ 450 = 42,630$

$\Delta B = \left(-\frac{4.42}{\#}\right)(42,630) + \frac{3.42}{\#}(37397) = -45,663$

8/4/76

After talking with Fluidyne it was decided to make ct. 1" thick with a 5" x 7.25 ring. Need to run this case. In addition, the bulkhead flanges are stiffer than those used in F.E. model; therefore, assume "0" rotation for these.

$h = 1"$ $\quad VF = 0$

$\lambda^4 = 88452 \quad \lambda^3 = 5129 \quad \lambda^2 = 297.41 \quad \lambda = 17.25 \quad K_1 = .9772 \quad K_2 = .9087$

$$m_\alpha = \frac{180 \sin 26.92}{2(17.25)} H = 2.36 H$$

$$\frac{(2)(297.41)(\sin 26.92)}{(1.1)(.9772)}(2.36H) - \left[\frac{(180)(17.25)\sin^2 26.92}{(11)}(1.53) + \frac{21.5^2}{(7.25)(5)}\right]H$$

$$= -\frac{(1-.3)(170)^2 119 \sin 26.92}{2(1)} - \frac{119(180)(81.5)^2 \cos 26.92}{2(5)(7.25)}$$

$$H = \frac{-2.361 \times 10^6}{-761} = 3102$$

$m_\alpha = 7321$

$$T_p = \frac{(6)(7321)}{1} - 3102 + 10710 = 51,535$$

This stress is less than 52.5 ∴ this design is acceptable even with zero rotation of bulkhead flange.

EXTERNAL PRESSURE RATING OF GATES

Using ASME CODE VIII DIV I

$$A = \frac{.125}{R/t} = \frac{.125}{180}(.75) = 5.21 \times 10^{-4}$$

From Fig UHT 28.1 $B = 7,600$

This chart does not specifically pertain to 9% Ni but it contains the same class of materials

$$P_a = \frac{B}{R/t} = \frac{(.75)\,7,600}{180} = 31,667$$

The external design pressure for the gate is 40 psi ∴ gate do not meet code

From Theory of Elastic Stability, p. 517

$$P_{cr} = \left[1 - .175\left(\frac{\theta - 20^\circ}{20^\circ}\right)\right]\left(1 - \frac{\sigma_{cr}}{\sigma_{yp}}\right) \cdot 3E\left(\frac{h}{a}\right)^2$$

$$P_{cr} = \left[1 - .175\left(\frac{26.5 - 20}{20}\right)\right]\left[1 - \frac{(.6)(180)}{(.75)\,400}\right] 13.12 \times 10^6 \left(\frac{.125}{180}\right)^2$$

$P_{cr} = 136$ psi

$$F.S. = \frac{136}{40} = 3.4$$

For 1" thk S.t. :-

$$A = \frac{.125}{180} = 6.9 \times 10^{-4} \Rightarrow B = 10{,}000 \Rightarrow P = 56 \text{ psi}$$

∴ 1" dish meets external pressure reqmts.